PPIC WATER POLICY CENTER

CALIFORNIA'S WATER

- CLIMATE CHANGE AND WATER
- THE COLORADO RIVER
- ENERGY AND WATER
- MANAGING DROUGHTS
- PAYING FOR WATER
- PREPARING FOR FLOODS
- PROTECTING HEADWATERS
- PROVIDING SAFE DRINKING WATER
- THE SACRAMENTO–SAN JOAQUIN DELTA
- STORING WATER
- WATER FOR CITIES
- WATER FOR THE ENVIRONMENT
- WATER FOR FARMS

PPIC
PUBLIC POLICY
INSTITUTE OF CALIFORNIA

PPIC

Climate Change and Water

PPIC WATER POLICY CENTER

NOVEMBER 2018

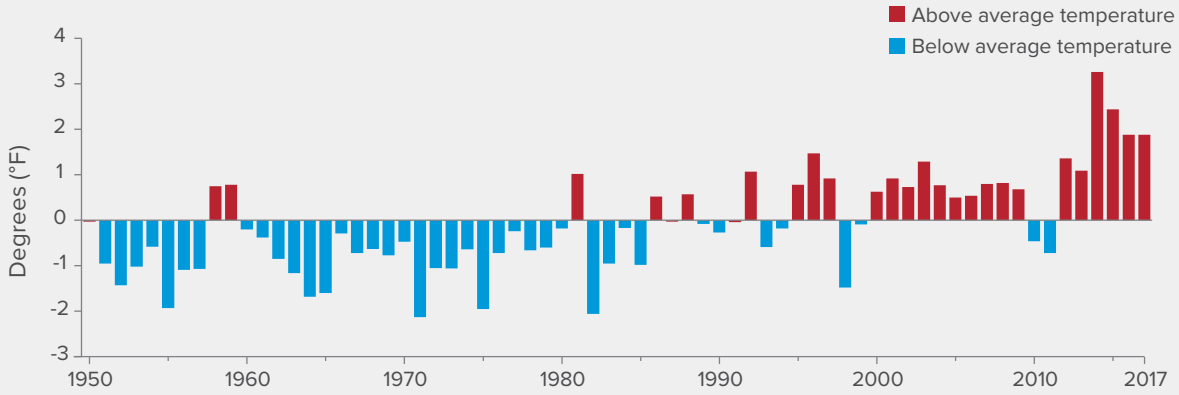
Climate change will affect California water management in many ways

California's climate is highly variable, with frequent droughts and floods. Climate models predict significant changes: warmer temperatures; shorter, more intense wet seasons; and more volatile precipitation—with wetter wet years and drier dry years.

Warming is already a reality. California's four warmest years on record have all occurred since 2014. Warming has complex and interrelated effects: it reduces the share of precipitation falling as snow, causes earlier snowpack melting and increased winter runoff, raises water temperatures, and amplifies the severity of droughts and floods. Sea level has been rising, increasing pressure on coastal flood defenses. This and larger freshwater floods threaten fragile levees in the Sacramento–San Joaquin Delta, an important water supply hub.

California is a national leader in addressing greenhouse gas emissions that contribute to climate change. However, water policies for adapting to a changing climate are still in early development. California's "water grid"—the linked network of storage and conveyance systems that connects most water use in the state—was designed for 20th-century conditions. Climate pressures will make it harder to simultaneously store water for droughts, manage flood risk, and protect freshwater ecosystems. Making this system more climate-ready is a major challenge that will require a concerted effort on multiple fronts, involving all levels of government and the private sector.

CALIFORNIA IS GETTING WARMER



SOURCE: Western Regional Climate Center.

NOTE: The figure reports degrees above or below the average statewide temperature (57.8° F) for 1981–2000.

Water supply management must adapt to a warmer, more variable climate

More intense floods and droughts will complicate water supply management. Rising temperatures and longer dry seasons could also increase demand for irrigation and the volume of water used by natural landscapes.

- **There are no easy substitutes for lost snowpack.**
  California's mountain snowpack has historically provided critical storage for meeting summer irrigation needs. A greatly reduced winter and spring snowpack—and increased precipitation variability—will stress supply. New surface storage can add flexibility, but it is costly, unlikely to provide abundant new supplies, and may become difficult to operate as runoff becomes more volatile. Given its high costs, seawater desalinization is also unlikely to yield large new supplies, though it could be a useful part of some urban water portfolios.

- **Adaptation will require changes in storage management.**
  Addressing snowpack loss and more variable precipitation will require coordinated management of water stored in surface reservoirs and groundwater basins. Conjunctive use—moving some water from reservoirs into groundwater basins for dry periods—will be especially valuable. This will require upgrades and expansion of water conveyance systems. Improving the reliability of conveyance through the Delta may allow more storage in the southern half of the state.

- **Urban water managers can adapt in many ways.**
  Options include expanding connections between urban systems with different supply sources, trading water with other cities and farmers, and using more treated wastewater and captured stormwater. Urban areas can also reduce water demand through reductions in water loss, technological innovations, and pricing and other incentives such as rebates for water-saving technology or replacing lawns with less thirsty landscaping.

- **California's agricultural sector can also adapt ...**
  With forward-looking strategies, productivity gains from technical improvements, and more flexible management of water supply, farm revenues can continue to rise. Key flexibility tools include water trading—which helps avoid the costliest water cuts during droughts—and groundwater banking—which enables farmers to store water during wet times for use during dry times.

- **... but adaptation will be more difficult without better groundwater management.**
  Farms have become increasingly reliant on groundwater to manage droughts, particularly in the Central Valley. Excessive pumping today will make it harder to manage aquifers in the future. Effective implementation of the 2014 Sustainable Groundwater Management Act, the first statewide effort to manage groundwater, can reduce the impacts of climate change on the farm sector.

Managing water to preserve species and ecosystems will become more difficult

Rising temperatures and changing runoff patterns may stress many native riverine and wetland species whose populations are already depleted by habitat loss, water operations, and other factors.

- **Approaches based on entire ecosystems will be needed.**
  Past approaches to managing environmental water have focused on improving habitats for one species at a time, typically once a species gets listed under state or federal endangered species acts. Future approaches should be adaptive and ecosystem-based to benefit multiple species.

- **Competition for water will probably increase.**
  Difficult trade-offs are likely. For instance, timing cold water releases from reservoirs to protect downstream salmon populations can mean less water for farms and cities at other times of the year. Reusing treated wastewater—a growing strategy for stretching supplies—can reduce water for the environment, particularly in urban settings.

- **State and federal policies will need to address trade-offs.**
  State policy—along with federal and state environmental laws—may need to be modified to manage difficult trade-offs both *between* human and environmental water uses and *among* environmental uses. For example, in warm, dry years increasing outflows for native fish in the Delta can conflict with maintaining cold water in reservoirs for salmon late in summer.

Flood planning must anticipate population growth and changing hydrology

Rising sea level, bigger and more frequent floods, growing population, and more building in vulnerable areas will increase the economic and social risks of flooding.

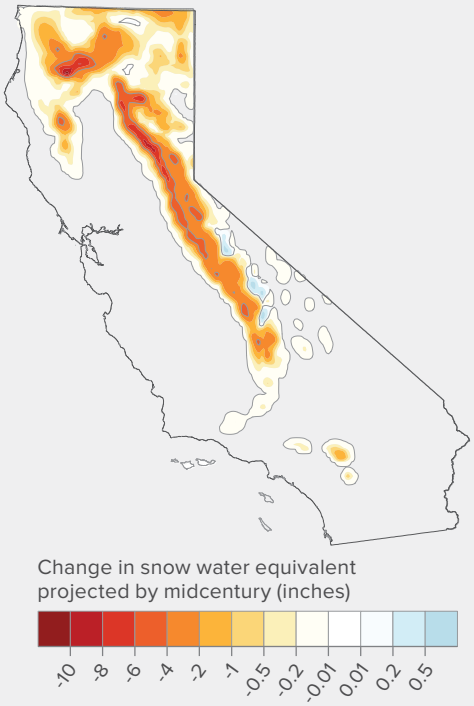
- **Major new investments will be needed.**
  To manage future urban and coastal flooding, state and local agencies must invest a minimum of $34 billion to improve dams, levees, coastal defenses, and urban stormwater systems. These infrastructure investments should be part of an integrated approach that also improves water supply and ecosystem health.

- **Flood management tools must be updated.**
  Regional flood management will require coordinated, forecast-based reservoir operations. This can be accomplished as part of conjunctive use strategies that make more room for floods by moving water into groundwater storage. Modest investments to improve forecasting—and better use of existing forecasting tools to reduce flood risk while increasing stored water—will significantly cut the costs of managing supply and responding to floods.
- **Nonstructural approaches will become more valuable.**
  To reduce risks from more volatile precipitation, California must go beyond infrastructure improvements and emphasize flood-smart land use planning, flood insurance, flood-proofing buildings, and emergency preparation. Local hazard mitigation plan requirements should include these approaches and anticipate future conditions.

Climate change will affect the water-energy relationship

In-state hydropower is a clean energy source that provides 15 percent of California's electricity on average. Snowpack changes will reduce the output of some hydropower reservoirs. Warming will also boost energy demand, particularly in summer months.

SHRINKING SNOWPACK REQUIRES CHANGES IN STORAGE MANAGEMENT



SOURCE: P. Ullrich et al., "California's Drought of the Future: A Midcentury Recreation of the Exceptional Conditions of 2012–2017" (*Earth's Future*, 2018).

NOTE: Figure shows the projected decline in snow water equivalent (the amount of water stored in snowpack) relative to 2017 for a similar wet year in midcentury (2047); the total statewide decline is projected at 25 percent.

- **The effects of warming on energy production will vary.**
  In most years the state's large, multipurpose reservoirs have enough storage to adapt to changes in the timing of snowmelt runoff. Not so for California's high-altitude hydropower reservoirs—among the most important sources of peaking power during hot summers. As temperatures rise, power availability from these reservoirs will shift to late winter and spring—when electricity demands are lower.
- **Some water management changes could increase energy demand.**
  Climate change and increased competition among users are likely to make surface water scarcer, particularly in agricultural areas. Farmers may respond by using more groundwater and switching to more efficient, pressurized irrigation systems. Both strategies will increase farm energy use. In urban areas, increasing temperatures will likely boost energy demand for cooling. Increased efficiency in urban water use and development of local water sources can reduce overall energy demand while helping communities adapt.

Looking ahead

California needs to adopt water supply, flood control, and ecosystem management strategies that will prepare the state for a changing climate and rising sea level.

Integrate climate change into water grid management. Adapting to a warmer, more volatile climate will require more flexible operations of storage and conveyance facilities and ensuring they work together as an integrated water supply and flood management system. Strategies include promoting conjunctive use; more flexible, forecast-based reservoir operations; and water trading. Conveyance investments are critical to support groundwater recharge and trading and to maintain water supplies drawn through the Delta, which could be disrupted by rising seas, seasonal flooding, and earthquakes. Conservation will continue to be important, especially in urban areas.

Prepare for bigger floods. In the next 20 to 50 years, floods will likely be quite different than what the state's flood management system was designed to handle, with substantially increased risks. In addition to more integrated management of the water grid, state and local agencies need to incorporate climate change projections into land use planning

decisions, flood insurance programs, the design of new flood infrastructure, and the rehabilitation of aging dams. Legislation may be required to encourage adoption of important risk-reduction strategies such as insurance.

Use recharge as a flood and supply management strategy. With increased storm intensity and changes in snowmelt timing, current reservoirs might need more space to manage larger floods. Managing reservoirs to recharge aquifers with excess floodwaters is a promising strategy that can also provide water supply and ecosystem benefits.

Upgrade information systems. Federal, state, and local agencies should upgrade information technology for water and ecosystem management. One priority is enhancing decision makers' ability to use existing water-related data. Implementation of the Open and Transparent Water Data Act (AB 1755) is an important first step. Strategic investments are also needed in modeling of weather and water supply and demand.

Develop an environmental stewardship strategy. Adapting to a warmer, more variable climate requires watershed level planning, especially to make ecosystems more drought-resilient. Actions can include water acquisitions, building ecosystem resilience through habitat restoration, and prioritizing conservation areas for greatest impact—including protecting environmental strongholds that can support species during droughts. These plans should inform water supply and flood management decisions.

Consider energy implications. Given the links between water and energy use, it is important to consider how California's water strategies affect energy demand, costs, and greenhouse gas emissions.

CONTACT A PPIC EXPERT

Jeffrey Mount
mount@ppic.org

Alvar Escriva-Bou
escriva@ppic.org

Ellen Hanak
hanak@ppic.org

CONTACT THE RESEARCH NETWORK

Daniel Cayan, dcayan@ucsd.edu
Frank Davis, frank.davis@nceas.ucsb.edu
Jay Lund, jrlund@ucdavis.edu
Daniel Swain, dlswain@ucla.edu
Barton "Buzz" Thompson, buzzt@stanford.edu
Paul Ullrich, paullrich@ucdavis.edu
Joshua Viers, jviers@ucmerced.edu
Robert Wilkinson, wilkinson@bren.ucsb.edu

READ MORE

- CLIMATE CHANGE AND WATER
- THE COLORADO RIVER
- ENERGY AND WATER
- MANAGING DROUGHTS
- PAYING FOR WATER
- PREPARING FOR FLOODS
- PROTECTING HEADWATERS
- PROVIDING SAFE DRINKING WATER
- THE SACRAMENTO–SAN JOAQUIN DELTA
- STORING WATER
- WATER FOR CITIES
- WATER FOR THE ENVIRONMENT
- WATER FOR FARMS

This series is supported by the annual sponsors of the PPIC Water Policy Center.

The PPIC Water Policy Center spurs innovative water management solutions that support a healthy economy, environment, and society—now and for future generations.

The Public Policy Institute of California is dedicated to informing and improving public policy in California through independent, objective, nonpartisan research. We are a public charity. We do not take or support positions on any ballot measure or on any local, state, or federal legislation, nor do we endorse, support, or oppose any political parties or candidates for public office. Research publications reflect the views of the authors and do not necessarily reflect the views of our funders or of the staff, officers, advisory councils, or board of directors of the Public Policy Institute of California.

Public Policy Institute of California
500 Washington Street, Suite 600
San Francisco, CA 94111
T 415.291.4400 F 415.291.4401
PPIC.ORG/WATER

PPIC Sacramento Center
Senator Office Building
1121 L Street, Suite 801
Sacramento, CA 95814
T 916.440.1120 F 916.440.1121

PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA

PPIC

The Colorado River

PPIC WATER POLICY CENTER

NOVEMBER 2018

The Colorado River is a major source of water for California

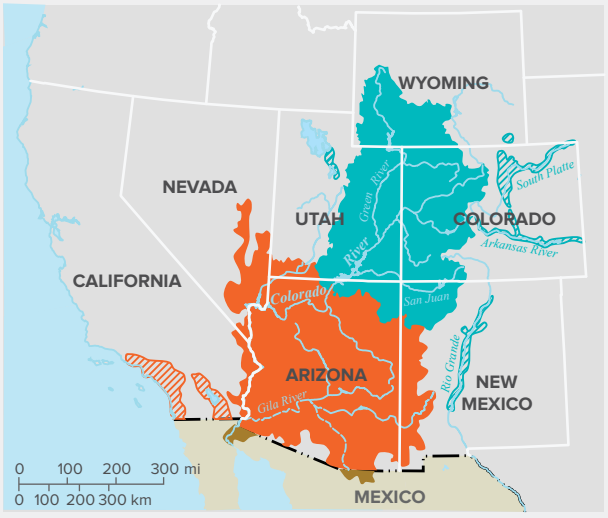
The Colorado River supplies roughly a third of all water for Southern California cities and suburbs. It also supports a large farming industry in Imperial and Riverside Counties.

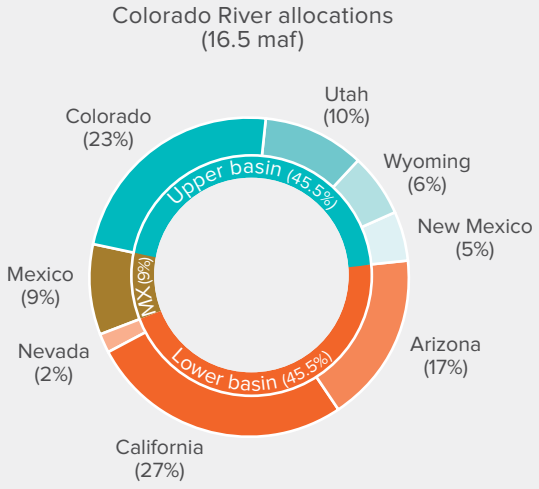
California shares this resource with six other states and Mexico—an interstate compact and an international treaty govern its water allocation. The US share is divided among four upper basin states (Wyoming, Colorado, Utah, and New Mexico) and three lower basin states (Arizona, Nevada, and California). The federal government plays a key role in managing infrastructure and supplies. Current agreements allocate 15 million acre-feet (maf) of water per year to the United States and 1.5 maf to Mexico. These allocations exceed average annual supplies, and long-term drought has sharply reduced storage in the major reservoirs. Climate change studies project an overall decline in the river's water, which will exacerbate the imbalance of supply and demand.

California was required to reduce its use of the river when other lower basin states began to draw their full allocations in the early 2000s. Cooperation among urban and agricultural agencies and the state—through a program known as the Quantification Settlement Agreement (QSA)—has made this possible. QSA programs make water available for transfers by lining earthen canals and improving irrigation efficiency, along with some land fallowing. But some of these programs reduce inflows to the Salton Sea—a vast saline sea in Southern California whose main water source is irrigation runoff from Imperial Valley farms.

Under the QSA, the state of California became responsible in 2018 for funding and implementing projects to mitigate the ecological and public health impacts of a shrinking Salton Sea. Californians also need to stay engaged in basin-wide efforts to bring the Colorado River Basin into balance.

CALIFORNIA IS A MAJOR USER OF COLORADO RIVER WATER





Upper Colorado Basin
Lower Colorado Basin
Colorado Basin in Mexico
Upper Colorado export areas
Lower Colorado export areas

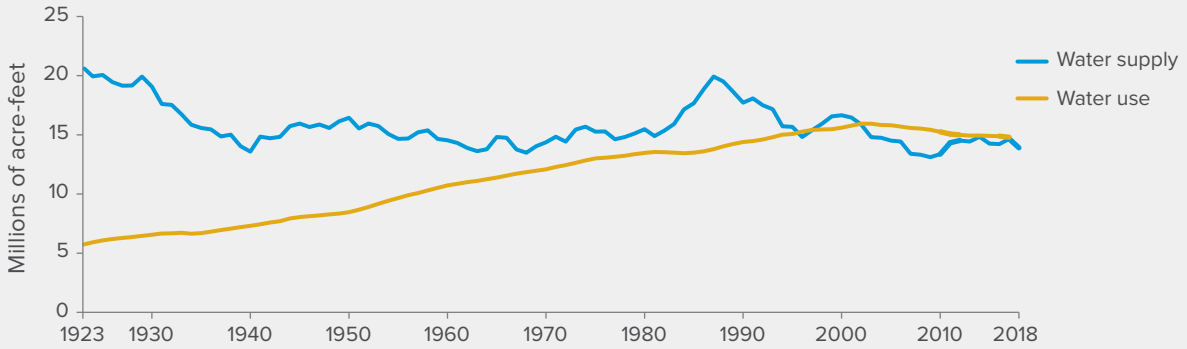
SOURCE: Author illustrations using maps from the US Bureau of Reclamation.

NOTES: The circle graph shows how the 16.5 million acre-feet (maf) are apportioned among the seven basin states and Mexico. These allocations over-estimate available supplies. Totals do not equal 100 percent because of rounding. Arizona's allocation includes 2.8 maf as a lower basin state and 0.05 maf as an upper basin state. American Indian tribes have rights to a significant share of this water in some states; some tribal rights are still awaiting settlement. Canals and aqueducts deliver most of California's allocation to agricultural and urban export areas outside the river basin. Export areas in the upper basin include the Denver metropolitan area, Albuquerque, and Salt Lake City.

The Colorado River Basin has a water budget deficit

A prolonged drought began in 1999. In 2007, all the US basin states adopted interim guidelines to avoid shortages by controlling supplies and allowing more flexible water management. In 2012, they made a similar agreement with Mexico (Minute 319, renewed in 2017 as Minute 323). Although basin-wide water use has declined in recent years, an imbalance between supplies and demands persists, due to reduced runoff and the lower states' excess consumption. The upper basin states use considerably less than their allocation.

WATER USE HAS BEEN OUTSTRIPPING SUPPLY IN THE BASIN



SOURCE: Adapted from US Bureau of Reclamation (USBR), *Colorado River Basin Water Supply and Demand Study* (2012), with updated historical supply and use data from USBR.

NOTES: The figure shows water use and supply as 10-year running averages. Supply estimates for 2016–18 and use estimates for 2017 are provisional.

- **Lower basin shortages affect parties differently.**
  The laws and policies that govern water allocation require the upper basin states to allow an average of 8.25 maf to reach the lower basin each year. Within the next few years, storage at Lake Mead—which serves the three lower basin states and Mexico—is expected to fall below the level that triggers usage cuts. Arizona, Nevada, and Mexico would lose supplies first. Although California has senior and relatively secure rights, Californians will benefit from solutions that reduce the costs of shortages for all parties. Arizona, Nevada, and California are negotiating a voluntary use-reduction agreement to slow Lake Mead's decline and avoid mandatory cuts.
- **Adapting to scarcity requires overcoming inflexible laws that govern the river.**
  Trading water and carrying over supplies for use in later years can reduce the costs of shortages. The laws that govern the river restrict these practices, but parties have begun to find work-arounds. For example, California and Nevada have stored water in Arizona groundwater basins, and some carryover storage is now allowed in Lake Mead. Cities in the upper and lower basins generally have junior rights, which are more likely to be reduced during shortages. They have funded conservation programs, primarily for upper basin irrigators, to help maintain water levels in Lakes Powell and Mead. American Indian tribes have also participated in these efforts. Recent declines in overall use suggest these kinds of innovations are beginning to reduce the imbalance of supply and demand.

California has been adapting to reduced Colorado River supplies

Within California, irrigators have first rights to 3.85 maf of the total 4.4 maf annual allocation. In the early 2000s, when California had to end a decades-long practice of using more than its share, the QSA helped cities avoid even deeper cutbacks. Although California is adapting, more challenges remain.

- **The QSA has encouraged regional collaboration and more flexible management.**
  State funding helped line canals, which reduced seepage and increased usable supplies. Urban agencies now also have several major long-term trades with irrigators for more than 500,000 acre-feet annually. These deals make water available from land fallowing and investments in more efficient irrigation. The Metropolitan Water District of Southern California is acquiring water from the Palo Verde Irrigation District, the Imperial Irrigation District (IID), and the Bard Water District. The San Diego County Water Authority has a large purchase agreement with IID.

- **Some QSA actions have involved trade-offs.**
  Lining the All-American Canal—a conduit along the Mexican border—saved water for California but reduced groundwater supplies for Mexican farmers. Water trades that involve land fallowing can reduce jobs and tax revenues in farming communities. Urban agencies have established funds to mitigate such negative impacts. Irrigation efficiency improvements at IID reduce irrigation runoff into the Salton Sea, accelerating environmental problems there.
- **Salinity is also a concern for California cities using Colorado River water.**
  By the time the Colorado River water reaches California, it has a higher salt content than most local supplies. This raises water treatment costs for urban agencies during droughts, when other sources are reduced.

Water use in the Colorado River Basin poses environmental challenges

Overallocation to farms and cities has harmed native species along the river. It has also dried up the delta where the river enters the Gulf of California, destroying once-important habitat for the Pacific Flyway. Conditions in and around the Salton Sea pose major ecological and public health challenges. Some of these issues are easier to address than others.

- **A multispecies conservation plan is in place on the lower Colorado River.**
  The first of its kind, this aquatic ecosystem plan was adopted in 2005 and aims to restore habitat and recover species between Lake Mead and the Mexican border.
- **Recent efforts to rewater the Colorado River Delta show promise.**
  In 2014, a pulse flow of water was sent down the dry riverbed in Mexico, briefly reconnecting the river to the ocean. This Minute 319 pilot project benefited riparian vegetation and wildlife. Minute 323 establishes modest annual base flows for delta restoration. The agreement also funds scientific research and project implementation.
- **The Salton Sea poses difficult challenges ...**
  In the 19th century the Salton Sea was known as the Salton Sink—a vast salt pan in the Colorado Desert. Levee failures in 1905 caused massive flooding, creating the modern Salton Sea. Since then, irrigation runoff from Imperial Valley farms has sustained it. A key stopover on the Pacific Flyway and once-popular recreation area, the sea is becoming hypersaline, destroying bird habitat. By reducing irrigation runoff, the QSA transfers exacerbate this problem; they are also causing the sea to shrink, worsening air pollution from increased dust along the exposed shoreline. Conditions could deteriorate rapidly from 2018 onward, when the transferring parties are no longer required to provide inflows to mitigate the reduced runoff.
- **... and the state is now in the driver's seat.**
  Under the QSA, California agreed to mitigate the effects of shrinking the Salton Sea. In 2017, the California Natural Resources Agency unveiled an initial 10-year restoration plan, with projects to reduce dust pollution and maintain bird habitat. State bond funds are available to launch this plan, and local and federal funds can also support mitigation.

Looking ahead

California and its partners in the Colorado River Basin must continue to adapt so that the river can keep providing essential economic, social, and environmental benefits to the region.

Build on recent efforts to manage demand. No significant opportunities exist to expand supplies in the Colorado River Basin, and available runoff appears to be in decline. Achieving balance will require additional efforts to reduce water use.

Foster flexible solutions to stretch scarce supplies. To reduce the economic costs of scarcity, parties will need to increase water trading and carryover storage. This is especially important for urban supply reliability throughout the basin, since cities generally have lower priority rights to river water.

Finalize drought planning efforts. With Lake Mead storage nearing levels that would trigger usage cuts in the lower basin, it is paramount that states finalize formal drought contingency plans. This is important for how the states share shortages, and it is also required to implement the new agreement with Mexico.

Protect local economies. The large share of water use in relatively low-revenue farming (80–90% of the total within the seven states) creates opportunities for trading, but such deals need to protect local economies. Rotational fallowing—where farmers take turns fallowing some land rather than permanently retiring it—is a promising option already being used in the Palo Verde Irrigation District. So is seasonal fallowing—where farmers cut back on lower-revenue crops in the hot summer months—now being piloted in Bard. Mitigation funds for fallowing, like those being offered in the Palo Verde and Imperial Irrigation Districts, are another option worth expanding.

Address public health and environmental problems at the Salton Sea. Timely implementation of the state's initial 10-year plan is essential to begin mitigating air and water quality impacts of a shrinking Salton Sea—a low-income region that already experiences much higher respiratory illness than the state as a whole.

Improve ecological conditions in the basin. Minute 323 extends the promising experiment of rewatering the Colorado River delta. Longer-term water and funding for habitat restoration will be needed beyond 2026, when this agreement expires.

Consider watershed connections. Because Southern California relies on both the Colorado River and water that flows through the Sacramento–San Joaquin Delta, shortages in the Colorado increase pressure on Delta supplies, and vice versa.

CONTACT A PPIC EXPERT

Ellen Hanak
hanak@ppic.org

Alvar Escriva-Bou
escriva@ppic.org

Brian Gray
gray@ppic.org

Jelena Jezdimirovic
jezdimirovic@ppic.org

Jeffrey Mount
mount@ppic.org

CONTACT THE RESEARCH NETWORK

Timothy Bradley, tbradley@uci.edu
Bonnie Colby, bcolby@email.arizona.edu
John Fleck, fleckj@unm.edu
Douglas Kenney, douglas.kenney@colorado.edu
Kurt Schwabe, kurt.schwabe@ucr.edu

READ MORE

- CLIMATE CHANGE AND WATER
- THE COLORADO RIVER
- ENERGY AND WATER
- MANAGING DROUGHTS
- PAYING FOR WATER
- PREPARING FOR FLOODS
- PROTECTING HEADWATERS
- PROVIDING SAFE DRINKING WATER
- THE SACRAMENTO–SAN JOAQUIN DELTA
- STORING WATER
- WATER FOR CITIES
- WATER FOR THE ENVIRONMENT
- WATER FOR FARMS

This series is supported by the annual sponsors of the PPIC Water Policy Center.

The PPIC Water Policy Center spurs innovative water management solutions that support a healthy economy, environment, and society—now and for future generations.

The Public Policy Institute of California is dedicated to informing and improving public policy in California through independent, objective, nonpartisan research. We are a public charity. We do not take or support positions on any ballot measure or on any local, state, or federal legislation, nor do we endorse, support, or oppose any political parties or candidates for public office. Research publications reflect the views of the authors and do not necessarily reflect the views of our funders or of the staff, officers, advisory councils, or board of directors of the Public Policy Institute of California.

Public Policy Institute of California
500 Washington Street, Suite 600
San Francisco, CA 94111
T 415.291.4400 F 415.291.4401
PPIC.ORG/WATER

PPIC Sacramento Center
Senator Office Building
1121 L Street, Suite 801
Sacramento, CA 95814
T 916.440.1120 F 916.440.1121

PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA

PPIC

Energy and Water

PPIC WATER POLICY CENTER

NOVEMBER 2018

Energy and water use in California are interconnected

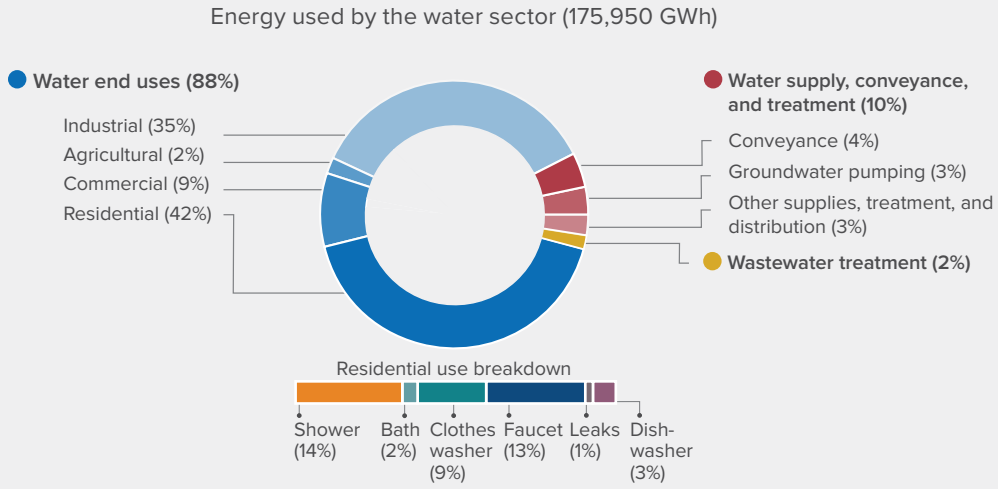
California's water system is energy intensive and may account for up to 10 percent of the state's greenhouse gas (GHG) emissions. According to the most recent estimates, approximately 20 percent of statewide electricity and 30 percent of natural gas for business and home use go to pumping, treating, and heating water. Water is also required to produce energy, including in hydropower generation, thermoelectric power plants, and oil and gas extraction.

Actions that improve water use efficiency can reduce energy consumption. Actions that improve energy efficiency can reduce impacts on water supply and quality. In contrast, some actions to boost the water sector's resilience to droughts can increase energy consumption. And measures to reduce the energy sector's water use can increase energy production costs and GHG emissions.

State policies have begun to promote managing water and energy in tandem. Some programs provide grants for efficiency, and the California Public Utilities Commission is working with utilities to quantify energy savings from water conservation. During the 2012–16 drought, the California Energy Commission (CEC) also launched an effort to reduce the energy sector's vulnerability to water shortages.

Continued population growth and a changing climate will increase pressures on water and energy supplies. To meet this challenge, California will need to continue adopting policies and technologies that improve management while being attentive to costs and trade-offs.

MOST ENERGY CONSUMED BY CALIFORNIA'S WATER SECTOR GOES TO RESIDENTIAL USE



SOURCE: California Public Utilities Commission, *Embedded Energy in Water Studies. Study 1: Statewide and Regional Water-Energy Relationship* (prepared by GEI Consultants/Navigant Consulting, Inc., 2010).

NOTES: The figure shows total energy use by California's water sector—175,950 gigawatts per hour (GWh). It includes water-related electricity (29% of the total) and natural gas (71%), converted to equivalent measures, for 2001—the last year for which end use estimates are available. Conveyance includes the energy used in the California State Water Project, the Central Valley Project, the Colorado River Aqueduct, and several regional water systems. Groundwater pumping is for urban and farm uses. Irrigation management, such as pressurization, is an agricultural water end use. Residential end uses include energy for heating water and running appliances, but not the embedded energy for supplying or treating water.

California's water sector is a major energy user

Although agriculture uses roughly four times more water than cities, cities use most water-related energy. End uses of water by retail customers—primarily for residential and nonfarm business purposes—make up almost 90 percent of water-related energy use. Pumping, conveying, and treating water and wastewater account for the rest. Opportunities for reducing energy use often depend on local conditions.

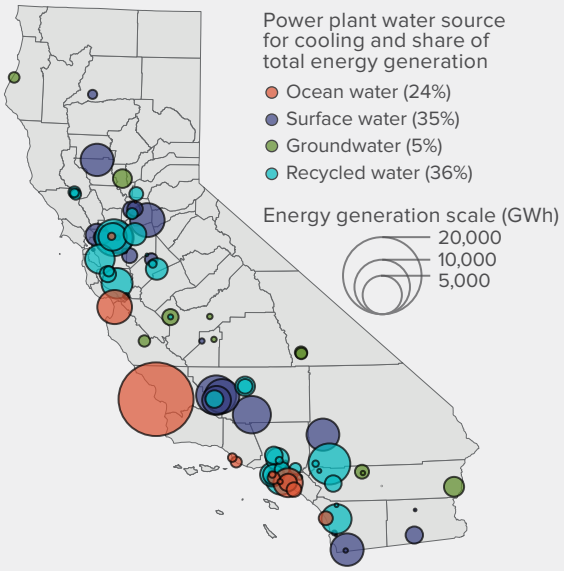
- **Water heating is a major energy use statewide.**
  Heating water requires a quarter of the total energy used in homes, so reducing hot water use and improving heating efficiency can significantly decrease energy consumption. Understanding behavioral factors and incentives that affect residential water use and employing data from smart metering technologies can improve conservation efforts.
- **Energy needs for delivering water vary greatly.**
  Delivering water relies on gravity in some places; in others it must be pumped. Southern California water imported from the northern part of the state is especially energy intensive because it must be pumped through the Sacramento–San Joaquin Delta and over the Tehachapi Mountains. Even within communities, large differences exist in energy required to deliver water to different neighborhoods.
- **Groundwater pumping also requires energy.**
  Pumping water from wells to supply both farms and cities requires energy. During the latest drought, farmers significantly increased groundwater pumping to replace lost surface water supplies. Especially in the San Joaquin Valley, long-term groundwater depletion has increased energy use because water must be pumped from greater depths. Implementing the 2014 Sustainable Groundwater Management Act is expected to stabilize groundwater levels and energy used for pumping over the long term.
- **Some new water sources are energy intensive.**
  To increase the reliability of water supplies, many urban agencies are investing in local sources, including recycled wastewater, stormwater, and desalination. These sources generally use more energy than local surface and groundwater supplies. But they can reduce water's total energy footprint if they displace more energy-intensive imported water—a possibility in Southern California.
- **Water-efficient irrigation technologies can increase energy use.**
  Improving irrigation system efficiency decreases the amount of water applied to fields. These upgrades can reduce the energy required to pump groundwater or to import water from other regions. But these technologies are often pressurized, requiring additional energy. And they enable expansion of acreage farmed, increasing both water and energy use.
- **Water conservation can be a cost-effective way to save energy.**
  One study found that the 25 percent urban water savings achieved during the latest drought resulted in 11 percent more electricity savings than electricity conservation programs run by energy utilities during the same period, at comparable cost.

Energy production requires reliable water supplies

California's in-state electricity generation includes thermoelectric (roughly 70%), hydropower (7% to 22% depending on precipitation and snowpack), and a growing share of other renewable sources, particularly solar and wind (up from 3% in 2010 to 18% in 2017). Thermoelectric and hydropower are highly dependent on water; solar photovoltaic and wind energy systems require little or no water—except in their manufacturing. Extracting oil and gas can also cause issues in water supply and quality.

- **Coastal power plants are changing water use to lessen environmental impacts.**
  These plants historically used "once-through cooling" systems, which take water from the ocean, circulate it through the plant's pipes to absorb heat, and discharge it back into the sea. To reduce harm to aquatic life, in 2010 the State Water Board announced that this practice must end. The "closed-cycle wet cooling" and "dry cooling" power systems being introduced now use less water and recycle it multiple times. These changes help protect ocean ecosystems, but the upgrades are expensive. Sometimes—especially with dry cooling—they are less efficient, raising other environmental concerns, such as air quality and GHG emissions.
- **Inland thermoelectric plants can be vulnerable to drought.**
  Most inland plants already use closed-cycle wet cooling systems. During the latest drought, some Central Valley plants that rely on surface water were at risk of shortages. The California Energy Commission is encouraging the industry to develop drought contingency plans and switch to more reliable recycled water supplies, already the cooling source for 36 percent of the state's power production.

MOST THERMOELECTRIC GENERATION IN CALIFORNIA RELIES ON RECYCLED WATER OR SEAWATER



SOURCE: Authors' calculations using data from the California Energy Commission.

NOTES: The map shows thermoelectric power plants—including nuclear, natural gas, geothermal, and biomass—with an installed capacity of more than 75 megawatts per hour. Bubble size represents the actual energy generated in 2015, and color represents the primary source of water used for cooling. The largest coastal plant, the Diablo Canyon nuclear power plant, generated 9.5 percent of all in-state electricity in 2015. It is slated to close by 2025.

- **Hydropower generation is also vulnerable to drought and a warming climate.**

Hydropower production relies on water in rivers and reservoirs. Between 2001 and 2017, in-state hydropower supplied an average of 15 percent of all electricity used, but this share was halved at the height of the latest drought. As the climate warms, loss of snowpack and increased winter runoff will likely reduce high-elevation hydropower in summer when electricity demand is highest.

- **Growth of renewables decreases the electricity sector's reliance on water.**

Senate Bill 100, enacted in 2018, requires that all of the state's electricity come from renewable and carbon-free resources by 2045. This bill also updates the 2030 target for renewable resources, from 50 to 60 percent. Although some renewables also need water—especially geothermal and concentrated solar power plants—shifting toward renewables will decrease the energy sector's overall water dependence.

- **Oil and gas production can affect water quality and local supplies.**

California is the nation's fourth-largest oil producing state, and it also produces some natural gas. To aid extraction, water is injected into wells. During this process, many wells also produce water mixed with oil and drilling fluids, which must be disposed of or treated. As of 2014, well owners must report water volumes used and produced. In 2016, oil and gas production used 5,100 acre-feet (af) of water and produced approximately 50,000 af. Roughly 8,500 of that met standards for domestic or irrigation use.

Looking ahead

California has been a pioneer in recognizing the nexus between water and energy. But it is still in the early stages of understanding synergies and trade-offs in managing the two sectors to benefit the economy and environment and meet climate policy goals.

Update estimates of the energy for water end uses. Much has changed in California's water sector over the past decade. Per capita urban water use has fallen considerably, and at least some of the more recent water savings are likely to persist. Updating estimates of water-related energy can help target effective actions.

Evaluate the benefits of water conservation and more energy-efficient water systems. To guide water and energy planning, the state should assess the costs and benefits of various options from both water and energy perspectives. For example, reducing the energy used to heat water may be an inexpensive way to reduce GHG emissions.

Recognize trade-offs of new water and energy technologies. To avoid unintended consequences, policymakers and managers need to anticipate such trade-offs. For instance, some new water sources can improve supply reliability but increase energy loads. Water-saving energy technologies like closed-cycle cooling can benefit aquatic habitat but increase costs and emissions.

Reduce the energy system's vulnerability to drought and a changing climate. The latest drought's combination of record warm temperatures, low snowpack, and reduced rainfall has provided a window into the future. State and energy-industry officials should continue efforts to understand and reduce the power grid's vulnerability to future droughts and a warming climate. Accommodating shifts in the timing of runoff and greater fluctuations in hydropower production will be essential.

Explore synergies in water operations and power grid management. As California increases the use of renewable energy, it will need to accommodate more variable supplies within its power grid. It may help to shift the timing of water heating, pumping, and treatment to periods when renewable sources are more available. With "pumped storage" systems, reservoirs can also act as a battery for excess renewable energy by storing water and converting it to hydropower when other renewables are less available.

Manage the quality and supply of water in oil and gas extraction. The reporting requirements on water use and production by oil and gas wells are an important first step to understand the water impacts of this sector. Better understanding of these water quality issues—including opportunities for safe disposal and safe reuse—is the next priority.

CONTACT A PPIC EXPERT

Alvar Escriva-Bou
escriva@ppic.org

Ellen Hanak
hanak@ppic.org

CONTACT THE RESEARCH NETWORK

Newsha Ajami, newsha@stanford.edu
David Jassby, jassby@ucla.edu
Katrina Jessoe, kkjessoe@ucdavis.edu
Jay Lund, jrlund@ucdavis.edu
Edward Spang, esspang@ucdavis.edu
Joshua Viers, jviers@ucmerced.edu
Robert Wilkinson, wilkinson@bren.ucsb.edu

READ MORE

- CLIMATE CHANGE AND WATER
- THE COLORADO RIVER
- ENERGY AND WATER
- MANAGING DROUGHTS
- PAYING FOR WATER
- PREPARING FOR FLOODS
- PROTECTING HEADWATERS
- PROVIDING SAFE DRINKING WATER
- THE SACRAMENTO–SAN JOAQUIN DELTA
- STORING WATER
- WATER FOR CITIES
- WATER FOR THE ENVIRONMENT
- WATER FOR FARMS

This series is supported by the annual sponsors of the PPIC Water Policy Center.

The PPIC Water Policy Center spurs innovative water management solutions that support a healthy economy, environment, and society—now and for future generations.

The Public Policy Institute of California is dedicated to informing and improving public policy in California through independent, objective, nonpartisan research. We are a public charity. We do not take or support positions on any ballot measure or on any local, state, or federal legislation, nor do we endorse, support, or oppose any political parties or candidates for public office. Research publications reflect the views of the authors and do not necessarily reflect the views of our funders or of the staff, officers, advisory councils, or board of directors of the Public Policy Institute of California.

Public Policy Institute of California
500 Washington Street, Suite 600
San Francisco, CA 94111
T 415.291.4400 F 415.291.4401
PPIC.ORG/WATER

PPIC Sacramento Center
Senator Office Building
1121 L Street, Suite 801
Sacramento, CA 95814
T 916.440.1120 F 916.440.1121

PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA

PPIC

Paying for Water

PPIC WATER POLICY CENTER

NOVEMBER 2018

Successful water management requires adequate, reliable funding

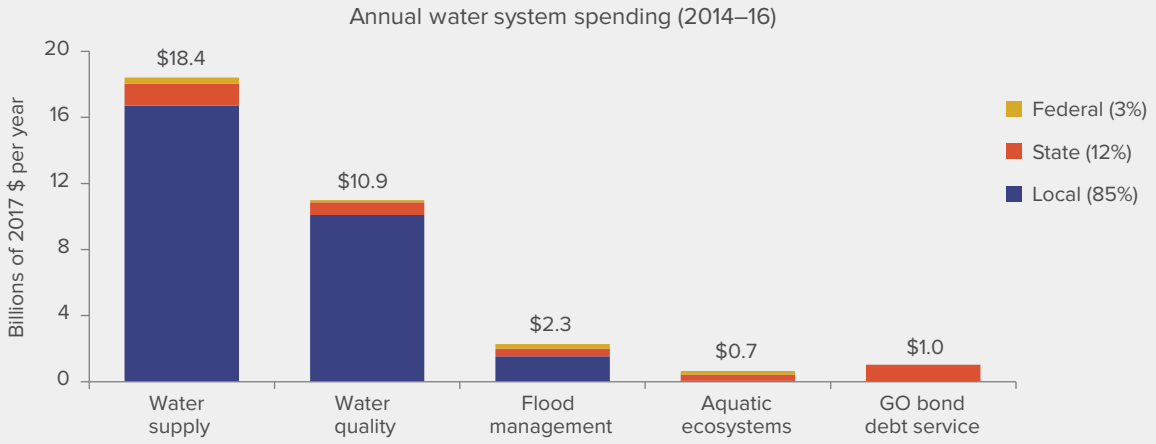
California's water system supplies cities and farms; prevents pollution of lakes, rivers, and coastlines; protects people and businesses from floods; and supports ecosystems. Many local, state, and federal agencies oversee this system and raise revenues from a variety of sources. Identifying funding gaps and finding adequate and reliable ways to fill them are perennial concerns.

Most public attention has focused on state general obligation bonds—voter-approved debt reimbursed with General Fund taxes. Eight bonds approved between 2000 and 2018 set aside roughly $24 billion for water projects. In November 2018, voters rejected Proposition 3—an $8.9 billion water bond.

State bonds are important, but they play a relatively minor role in funding California's water. Bonds typically provide less than $1 billion of the more than $33 billion in annual water-related spending. Local revenue—from water and sewer bills to taxes—provides 85 percent. The state contributes 12 percent and the federal government 3 percent.

California's urban water and wastewater agencies face some fiscal challenges, including how to balance their checkbooks during droughts when they collect less revenue. But overall they are in reasonably good fiscal health. Other management areas face critical gaps totaling $2–$3 billion annually—a result of legal constraints on local funding, a shrinking federal contribution, and unreliable state support. In California's $2.7 trillion economy, this problem is manageable. But dealing with it requires a focused effort and statewide leadership. Looking beyond bonds to fill gaps should be a top priority.

LOCAL UTILITIES RAISE MOST OF THE MONEY SPENT ON WATER IN CALIFORNIA



SOURCE: Updated from E. Hanak et al., *Paying for Water in California* (PPIC 2014).

NOTES: The figure reports average spending for 2014–16. Local expenditures exclude grants from higher levels of government. The water quality category includes management of wastewater and approximately $500 million for polluted stormwater and other runoff. GO bond debt service is repayment of state general obligation bonds.

Constitutional changes have disrupted local water finance

Local finance is the lifeblood of California's water system. But a series of constitutional amendments—Propositions 13 (1978), 218 (1996), and 26 (2010)—have made it harder to raise funds for local water services.

- **The changes have increased accountability, but with unintended consequences.** Proposition 218's rate-setting reforms improved transparency and accountability for local public agencies. But its simplistic cost-recovery requirement may inhibit sound local programs. The law specifies that rates cannot exceed the cost of providing a service. Some courts have ruled that conservation-oriented rates (called tiered or

budget-based rates) may violate the state constitution. This was a concern for utilities during the latest drought, as they struggled to adjust rates to promote conservation and stay fiscally sound.

- **Stricter voter requirements impede delivery of some essential water services.** New local taxes for water programs must get two-thirds voter approval—a much higher hurdle than the simple majority required for local general taxes or state ballot measures. Before Proposition 218, elected governing boards could approve new fees and assessments for flood and stormwater management. Now this requires a majority of landowners or two-thirds of all local voters. A 2017 state law may have improved the situation for stormwater management, by defining it as part of the sewer system. If upheld by the courts, this puts stormwater on par with water, sewer, and trash collection services, which are not subject to direct voter approval of new fees.

Urban water and sewer systems are performing reasonably well

Urban utilities have generally been able to raise funds to replace aging infrastructure and to comply with new treatment requirements. Investments in conservation, water reuse, and local conveyance and storage since the 1990s have helped prepare cities for drought. But raising rates is unpopular, and some agencies—particularly smaller ones—have fallen behind on needed maintenance and investments.

- **Keeping water affordable for low-income households will be a challenge.** Water and sewer bills have been rising to keep pace with investment needs. For most Californians, these charges are a small share of income. Not so for low-income households. Proposition 218 restricts publicly owned utilities from providing "lifeline" discounts for more equitable pricing. These restrictions do not apply to privately owned water, energy, and telephone utilities, where lifeline rates are common.
- **Integrated water management is hard to fund locally, despite its benefits.** Integrated water management involves agencies with different responsibilities collaborating to improve overall system performance. But Proposition 218's cost-recovery requirements hinder water and wastewater agencies from sharing costs for activities that extend beyond their mandates. And financially weaker partners overseeing other programs have trouble contributing their share. Funding new programs for sustainable groundwater management will also be challenging.

California's water system has multiple fiscal orphans

California is failing to adequately fund services that protect public health and safety and the environment, such as providing safe drinking water in small, low-income communities; managing floods; controlling stormwater and other polluted runoff; and managing freshwater ecosystems and headwater forests.

- **State bonds help fill gaps, but they have drawbacks.** Since 2000, state bonds have helped fill funding gaps. But bonds are not a reliable long-term source, and they generally don't cover operating and maintenance costs. Bonds are repaid with interest from the state General Fund. During economic downturns, repayment can take funds from other important state programs.
- **Paying for water's fiscal orphans requires other funding sources.** California needs a broader, more reliable mix of state and local funding sources, including new fees and taxes. Some examples are parcel taxes, small surcharges on water and chemical use, and small increments to the sales tax. Such measures have been proposed at the state level, and some California communities and other states already employ them.
- **Some poor communities can't afford safe water.** Providing safe and reliable drinking water is a special challenge in small rural communities, where costs per household are high and local funding resources are scant. Common problems include nitrate from farm runoff and other groundwater contaminants, such as naturally occurring arsenic. These communities are also vulnerable to water shortages during droughts. State bonds and other programs support some infrastructure upgrades and consolidation with larger water systems. But more durable funding is needed—including for operations and maintenance. The cost of solving this problem is modest compared to other gap areas.

- **Federal funding for flood projects has been inadequate.**
  Federal policy authorizes matching grants for flood protection projects—up to 65 percent of costs. But this is mostly unfunded, leading to a large investment backlog. Federal contributions are shrinking, and state bond funds have not come close to filling this gap. Voters in some communities have approved modest local cost shares, but it will be much harder to pass the larger charges needed to fill the gap.
- **Constitutional changes have hit stormwater agencies hardest.**
  Stormwater management once focused solely on draining streets after storms. Mandates have expanded to prevent pollution of rivers, lakes, and beaches by limiting discharges and cleaning runoff before it enters waterways. Even if courts uphold recent legislation that defines stormwater as part of the sewer system, it may be hard to raise funds for cleanup that mainly benefits downstream communities. Recent state bonds have only contributed modestly to this area.
- **Most ecosystem management programs lack a reliable funding base.**
  Although recent state bonds devote some funds to ecosystems, these do not provide consistent ongoing support. Funding for mandatory ecosystem investments within new projects is usually straightforward. But most environmental problems result from past water- and land-use practices, and responsibility for fixing them is often disputed. Some communities have approved special taxes to support their watersheds, but the two-thirds voter requirement limits this approach.
- **Protecting headwater forests requires increased investments.**
  Wildfire suppression consumes most spending by state and federal forest agencies—about $2 billion a year, versus just $100 million for forest management projects. Focusing on fire suppression prioritizes the treatment of symptoms rather than the causes of unhealthy forests. Headwater forest health will continue to decline without a strategy and funding to increase the pace and scale of management.

CALIFORNIA NEEDS TO GO BEYOND BONDS TO CLOSE FUNDING GAPS

Gap area	Annual gap ($ millions)	Onetime infusion from GO bonds passed since 2014 ($ millions)	Other long-term funding options
Safe drinking water in small, poor communities	$30–160	Up to $370	▪ Statewide surcharges on water, chemical use
Flood protection	$800–1,000	$845	▪ Developer fees ▪ Property assessments ▪ Special state, local taxes
Stormwater management	$500–800	$300	▪ Developer fees ▪ Property assessments ▪ Special state, local taxes ▪ Surcharges on water, chemical, or road use
Freshwater ecosystem management	$400–700	$3,987	▪ Special state, local taxes ▪ Surcharges on water use, hydropower production
Integrated management	$200–300	$860	▪ Special state, local taxes ▪ Surcharges on water use

SOURCES: E. Hanak et al., *Paying for Water in California* (PPIC, 2014), and text for Proposition 1 (approved in November 2014) and Proposition 68 (June 2018).

NOTES: Most safe drinking water funds prioritize disadvantaged communities, but of all sizes. Another $260 million for small community wastewater systems is available from these bonds. Freshwater ecosystem management funds include programs for aquatic habitat and watersheds, plus $1.35 billion from Proposition 1 storage projects reserved for ecosystem benefits. Integrated management funds include integrated regional water management and sustainable groundwater management.

Looking ahead

California must fill critical funding gaps for essential functions: ensuring clean drinking water for all residents; protecting residents from flooding; keeping beaches, rivers, and lakes safe for recreation; safeguarding threatened freshwater

ecosystems; and improving headwater forest health. Action is also needed to avoid funding problems for urban water and wastewater systems, which face rising costs and legal uncertainties, and to encourage more integrated water management.

Use new bond funds to fill real gaps. Recent bonds have infused billions of dollars into the water system. The legislature and state agencies should make sure these state funds are going to programs and agencies that lack an adequate funding base—not simply substituting for local funds.

Look beyond bonds. One legislative priority is to help local agencies raise needed funds by expanding local funding authority and providing guidance to the courts on how their interpretations of Proposition 218 may affect water financing. Another priority is to enact new state fees and taxes to boost funding for fiscal orphans.

Adjust local water rates to cope with drought. Rate structure adjustments and drought surcharges are needed to reduce the fiscal effects of conservation and encourage continued urban investment in drought resilience. Utilities must effectively communicate the reasons for rate changes during drought. They must also build strong administrative records of ratemaking decisions to meet potential Proposition 218 court challenges.

Clarify constitutional requirements. To solidify local funding, voters may need to approve constitutional changes that address the unintended consequences of previous amendments—while retaining transparency and accountability requirements. These might include clarifying Proposition 218's cost-recovery requirements (to allow for conservation and lifeline rates) and stipulating that flood programs should be treated like water and wastewater programs.

CONTACT A PPIC EXPERT

Ellen Hanak
hanak@ppic.org

Caitrin Chappelle
chappelle@ppic.org

Brian Gray
gray@ppic.org

Henry McCann
mccann@ppic.org

CONTACT THE RESEARCH NETWORK

Newsha Ajami, newsha@stanford.edu
Ken Baerenklau, ken.baerenklau@ucr.edu
Van Butsic, vanbutsic@berkeley.edu
Katrina Jessoe, kkjessoe@ucdavis.edu
Jay Lund, jrlund@ucdavis.edu
Dean Misczynski, dean.misczynski@gmail.com
David Mitchell, mitchell@mcubed-econ.com

READ MORE

- CLIMATE CHANGE AND WATER
- THE COLORADO RIVER
- ENERGY AND WATER
- MANAGING DROUGHTS
- PAYING FOR WATER
- PREPARING FOR FLOODS
- PROTECTING HEADWATERS
- PROVIDING SAFE DRINKING WATER
- THE SACRAMENTO–SAN JOAQUIN DELTA
- STORING WATER
- WATER FOR CITIES
- WATER FOR THE ENVIRONMENT
- WATER FOR FARMS

This series is supported by the annual sponsors of the PPIC Water Policy Center.

The PPIC Water Policy Center spurs innovative water management solutions that support a healthy economy, environment, and society—now and for future generations.

The Public Policy Institute of California is dedicated to informing and improving public policy in California through independent, objective, nonpartisan research. We are a public charity. We do not take or support positions on any ballot measure or on any local, state, or federal legislation, nor do we endorse, support, or oppose any political parties or candidates for public office. Research publications reflect the views of the authors and do not necessarily reflect the views of our funders or of the staff, officers, advisory councils, or board of directors of the Public Policy Institute of California.

Public Policy Institute of California
500 Washington Street, Suite 600
San Francisco, CA 94111
T 415.291.4400 F 415.291.4401
PPIC.ORG/WATER

PPIC Sacramento Center
Senator Office Building
1121 L Street, Suite 801
Sacramento, CA 95814
T 916.440.1120 F 916.440.1121

PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA

PPIC

Protecting Headwaters

PPIC WATER POLICY CENTER

NOVEMBER 2018

California needs to manage its main water source more effectively

The headwaters—or upper watersheds—of California's mountain regions supply most of the water for farms, cities, and freshwater ecosystems. These heavily forested areas are a key part of the state's natural water infrastructure—and essential for a sustainable future. They also support habitat for much of California's biodiversity, including threatened and endangered wildlife. They provide timber, forage, and recreation; sequester carbon; and are rich in cultural and historical value. But the health of these headwaters is at risk.

The latest drought's hot, dry conditions led to record tree mortality and wildfires in headwaters across the state—a glimpse of what the future might hold. Conifer forests in the Sierra Nevada and southern Cascades are particularly vulnerable. Historic forest and fire management practices have made these forests overly dense, increasing their susceptibility to drought, insect attacks, and extreme wildfires.

Despite recent progress in collaborative management, a need remains for targeted actions and long-term investments at local, state, and federal levels. Better collaboration with federal agencies is essential, as they own about two-thirds of the major headwater region. Barriers to large-scale management include the challenging task of building public acceptance for forest fuel reduction; the patchwork of federal, industrial, and family land ownership; and the lack of infrastructure and markets for forest products removed to improve forest health.

THE FEDERAL GOVERNMENT OWNS MOST OF THE LAND ABOVE THE STATE'S MAJOR RESERVOIRS

SOURCE: V. Butsic et al., *Improving the Health of California's Headwater Forests* (PPIC, 2017), Figure 1.

NOTES: The figure depicts ownership of lands, including montane conifer forests, that drain into the major water supply reservoirs of the Central Valley. The US Forest Service, National Park Service, and Bureau of Land Management own about two-thirds of this major headwater area and more than half of all forestland in California.

Upper watersheds are California's natural infrastructure

Headwaters naturally collect, treat, convey, and store water. The mountainous forests of the Sierra Nevada and southern Cascade ranges are critical for the state's water and energy supplies and for local economies.

- **Headwaters provide most of the runoff ...**
  Mountainous headwaters occupy less than one-fifth of the state but provide most of its surface water. Many smaller headwaters collect and convey water and contribute to local supplies.

- **... and they store water.**
  Roughly a third of California's annual water supply is stored as snowpack that melts during the spring and early summer when demands are high. Water is also stored in the ground and released through springs. More than 40 percent of the inflow to Shasta Reservoir—the state's largest—comes from springs in the northern Sierra Nevada and southern Cascade ranges.

- **Headwaters also supply high-quality water ...**
  Water from the mountainous headwaters is of exceptionally high quality. Much of the Bay Area, for example, can avoid the costs of filtration because of water sourced directly from the Sierra Nevada.

- **... and help reduce greenhouse gas emissions.**
  On average, 15 percent of electricity comes from hydropower produced in the upper headwaters—a clean source of energy with low greenhouse gas emissions. Headwater forests also sequester carbon by storing it in plants and soil.

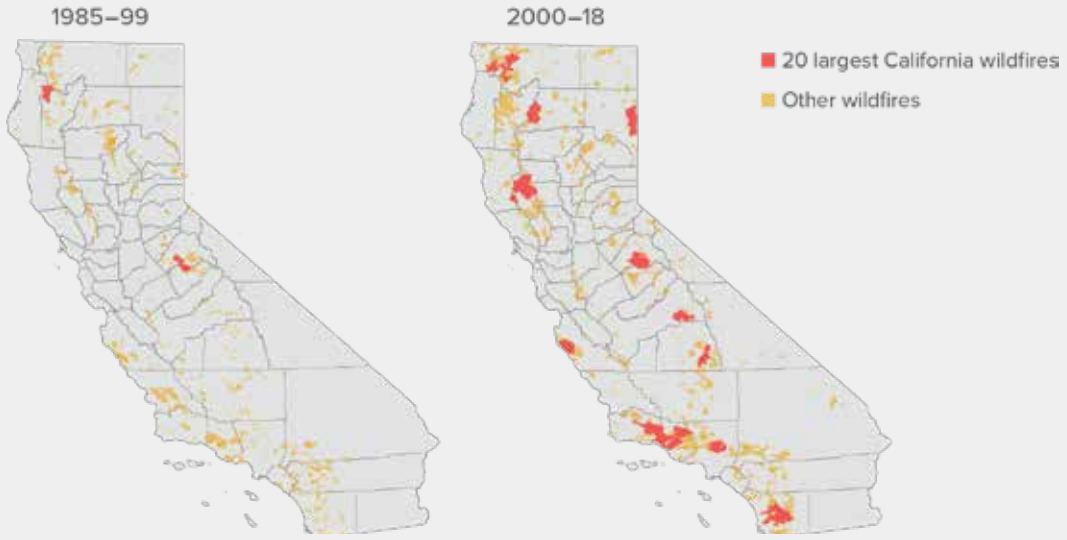
- **Rural economies depend upon this natural infrastructure.**
  Although not a large part of the state's economy, headwater forests can generate jobs in local towns. This includes recreation and tourism, public resource management, industrial timber harvesting, and grazing.

Wildfires pose a major challenge for the state, and the risk is growing

California faces a significant crisis in managing its mountainous headwater forests—fueled by drought, a warming climate, and decades of practices that resulted in overly dense growth. Recent record-setting fires mostly occurred outside this region, but the issue must be addressed to help prevent future large, high-severity fires.

- **Extreme wildfires are becoming larger and more destructive.**
  The size and severity of California's wildfires have increased since mid-century. Nearly three-quarters of the state's largest wildfires have occurred since 2000. Fire behavior is also becoming more extreme. For example, some wildfires now continue to grow throughout the night, which makes them harder to control.

MOST OF CALIFORNIA'S LARGEST WILDFIRES HAVE OCCURRED SINCE 2000



SOURCE: Adapted by the authors from Cal Fire, Fire and Resource and Assessment Program fire perimeter database.

NOTES: Cal Fire's fire perimeter database is a complete record of acreage burned by wildfires from 1985 to 2017. The 20 largest wildfires are measured in terms of acres burned. The figure includes two top-20 fires from 2018 (the Carr and Mendocino Complex Fires) and excludes three top-20 fires that burned before 1985. The two top-20 fires from 1985 to 1999 burned 287,000 acres, and the 15 top-20 fires from 2000 to 2018 burned 3,326,000 acres.

- **Extreme fires have many negative impacts.**
  Large wildfires can generate air pollution across a wide area, creating significant public health risks. Erosion of ash and exposed soils can reduce water quality and reservoir storage capacity. Risks of flooding and landslides also increase.
- **Communities are expanding into areas with high fire risk.**
  Having more people and buildings in high-risk areas threatens public safety, raises the cost of fighting fires, increases the potential for economic losses, and heightens the potential for human-caused fires.
- **Different landscapes have different wildfire drivers.**
  In the Sierra Nevada and southern Cascades, fire suppression and past timber harvesting practices have created exceptionally dense mountainous forests. Severe tree mortality and warming temperatures have primed these forests for large, extreme wildfires. So far, most of the record-breaking wildfires have occurred elsewhere, in oak woodlands and chaparral. Wildfire risk in these areas is also driven by other factors, such as wind.

Managing headwater forest health is complicated

Despite clear understanding of the approaches that can improve the health of California's mountainous headwater forests, regulatory and financial barriers persist. And other challenges increase the complexity of reducing wildfire risk.

- **Forest management rules prioritize short-term objectives over long-term resilience.** California's forest management regulatory framework often protects forests from short-term impacts at the expense of long-term resilience. Tools like prescribed fire and mechanical thinning (selective removal of small- and medium-size trees) are essential for improving long-term resilience to drought, insects, and fire in the major headwater regions. But because they can also result in short-term negative impacts, their use is often discouraged.
- **US Forest Service and family forest owners face management barriers.** Collectively, the US Forest Service (USFS) and private families own about three-quarters of the 15-million-acre Sierra Nevada and southern Cascade headwater forests. The decline of timber harvesting and the growing cost of fire suppression have limited USFS's capacity and funding to manage their vast holdings. Family owners are less likely to manage their lands because of high per-acre costs of forestry work.
- **California lacks the market and infrastructure to support large-scale management.** Markets and infrastructure for forest products were once able to support large-scale management in headwater forests. But now lumber mill closures and forest access road deterioration have increased costs, making some fuel reduction projects prohibitively expensive.
- **Tools for reducing fire risks vary across landscapes.** Strategies that work in mountainous headwater forests—notably mechanical thinning and prescribed burning—may not be effective elsewhere. In Southern California chaparral, where dense communities have expanded into fire-prone areas, it works better to suppress fires aggressively and to create firebreaks around structures. And in oak woodlands, grazing to reduce fire-prone vegetation and creating firebreaks can help make fires easier to manage.
- **In addition to declining forest health, headwaters have other issues.** In some places, historic mining has affected water quality, particularly with acid mine drainage and mercury. Past intensive timber harvesting has impaired streams and wetlands across the state. Overgrazing has damaged many meadows and their streams. Hydropower and water supply dams block fish migration and change the timing, magnitude, and temperature of flows needed to support native fish.

Looking ahead

To sustain its major headwater areas and reduce the risk of extreme fire, California needs targeted management actions and long-term funding solutions.

Increase active management of unhealthy forests. Reducing fuel accumulation and thus the risk and severity of wildfire requires more frequent prescribed and managed wildfires in headwater forests. Some areas will also need tree removal through mechanical thinning. Implementing these strategies will require both easier federal and state permitting and community acceptance. A new law will help by streamlining permitting for forest health projects on private and federal lands and providing several years of dedicated funding to manage forests. Project-level collaborations between federal and state agencies, local governments, communities, and the forest products sector will be essential to confront the massive scale of the state's forest health crisis.

Use creative funding partnerships to expand forest management. Funding to improve forest health is needed not just for new management projects but also for long-term maintenance. Mobilizing those who benefit from healthy headwater forests may be an effective way to expand long-term stewardship. Federal forest management policies allow external partners to provide financial and technical support to work on federal land. In spring 2018, Governor Brown directed state agencies to make more effective use of these policies.

Lower the barriers to family forest management. State forest, water, and air resource agencies have been directed to lower barriers to fuel management on family forests. Agencies can accomplish this by streamlining the permitting process and providing technical and financial support.

Develop a better understanding of forest management benefits and cost savings. Some large forest management projects are motivated by an interest in reducing future wildfire impacts on water supply and hydropower infrastructure. But to expand this approach, California needs better field-level information about how fuel reduction benefits water quality and runoff timing, along with carbon sequestration and air quality. Large-scale experimental programs are needed to measure and track these benefits over time.

Consider investments in forest products infrastructure. Decline in the state's forest products industry has greatly reduced infrastructure needed for forest management. To make it more economically viable, support for lumber mills and biofuel generation plants near forests may be warranted.

Reduce urban encroachment into wildland areas. California needs to discourage development in fire-prone landscapes, which increases the risks and potential costs of wildfire. One option is to create incentives for development in areas that can be defended effectively from fire.

Build social awareness of the risks of status quo management. Despite growing public awareness of the problems afflicting headwater forests and the resulting increased wildfire risk, resistance to large-scale fuel management remains an impediment to action. USFS and Cal Fire could help build awareness of proactive management's value by ramping up public education on these issues.

CONTACT A PPIC EXPERT

Jeffrey Mount
mount@ppic.org

Ellen Hanak
hanak@ppic.org

Henry McCann
mccann@ppic.org

Brian Gray
gray@ppic.org

CONTACT THE RESEARCH NETWORK

Van Butsic, vanbutsic@berkeley.edu
Ted Grantham, tgrantham@berkeley.edu
Yufang Jin, yujin@ucdavis.edu
Scott Stephens, sstephens@berkeley.edu
Joshua Viers, jviers@ucmerced@edu

READ MORE

- CLIMATE CHANGE AND WATER
- THE COLORADO RIVER
- ENERGY AND WATER
- MANAGING DROUGHTS
- PAYING FOR WATER
- PREPARING FOR FLOODS
- PROTECTING HEADWATERS
- PROVIDING SAFE DRINKING WATER
- THE SACRAMENTO–SAN JOAQUIN DELTA
- STORING WATER
- WATER FOR CITIES
- WATER FOR THE ENVIRONMENT
- WATER FOR FARMS

This series is supported by the annual sponsors of the PPIC Water Policy Center.

The PPIC Water Policy Center spurs innovative water management solutions that support a healthy economy, environment, and society—now and for future generations.

The Public Policy Institute of California is dedicated to informing and improving public policy in California through independent, objective, nonpartisan research. We are a public charity. We do not take or support positions on any ballot measure or on any local, state, or federal legislation, nor do we endorse, support, or oppose any political parties or candidates for public office. Research publications reflect the views of the authors and do not necessarily reflect the views of our funders or of the staff, officers, advisory councils, or board of directors of the Public Policy Institute of California.

Public Policy Institute of California
500 Washington Street, Suite 600
San Francisco, CA 94111
T 415.291.4400 F 415.291.4401
PPIC.ORG/WATER

PPIC Sacramento Center
Senator Office Building
1121 L Street, Suite 801
Sacramento, CA 95814
T 916.440.1120 F 916.440.1121

PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA

PPIC

Providing Safe Drinking Water

PPIC WATER POLICY CENTER

NOVEMBER 2018

Not every Californian has access to safe and reliable drinking water

Most Californians have safe drinking water. The vast majority of the state's nearly 3,000 community water systems consistently meet safety standards, and public health violations are both rare and quickly addressed. But some regions have ongoing water quality challenges, mostly affecting smaller, rural, disadvantaged communities. Although this is a persistent issue, it is also a manageable one with the right leadership and resources.

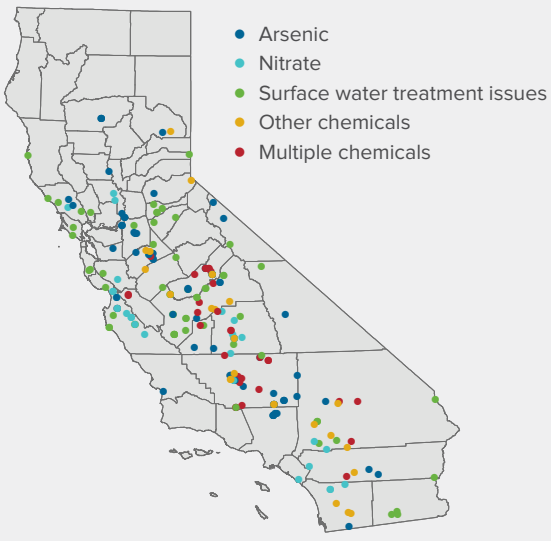
Local, state, and federal agencies all have responsibilities for ensuring adequate and safe drinking water under the federal Safe Drinking Water Act and related state laws. In 2012, California's legislature passed the Human Right to Water Act, which recognizes that "every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes."

The State Water Board now has primary oversight of safe drinking water programs, and in 2015 it created a special office to focus on the problems of disadvantaged communities. Even so, some still lack safe water.

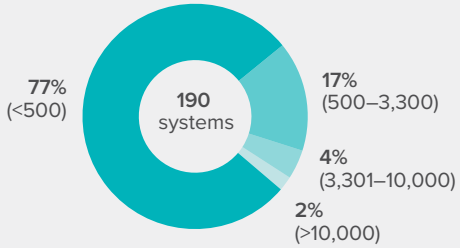
In addition, some rural communities saw their water supply disappear during the 2012–16 drought, as their wells went dry from falling groundwater levels. The state stepped in with emergency assistance, but many of these communities remain vulnerable.

SOME WATER SYSTEMS HAVE BEEN UNABLE TO PROVIDE SAFE DRINKING WATER FOR YEARS

Noncompliant water systems by type of pollutant



Systems with violations for three or more years
(size by population served)



SOURCES: Developed by the authors using data from the State Water Board's Human Right to Water (HR2W) portal and the US Environmental Protection Agency's ECHO portal.

NOTES: The map shows the 233 community water systems (serving 357,000 people, or 0.9% of the population) that were out of compliance in July 2018 as reported in HR2W. The circle chart uses ECHO to obtain data on quarters out of compliance for these 233 systems; only 7 had been out of compliance for less than a year. Since HR2W is updated monthly and ECHO is updated quarterly, the two data sets do not match up perfectly.

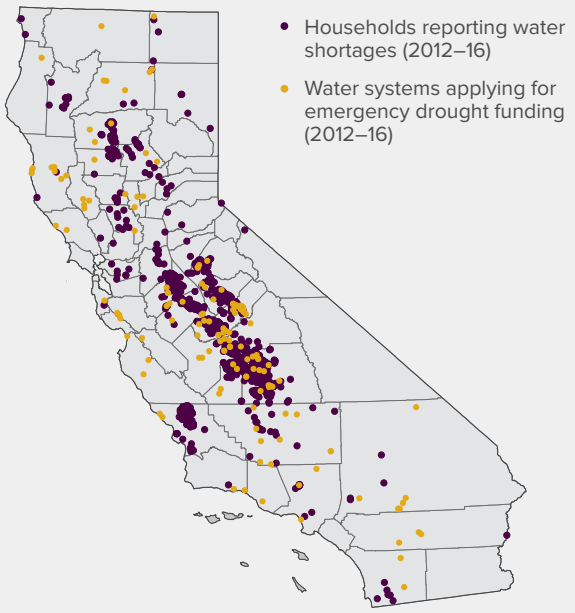
Some communities are routinely unable to provide safe drinking water

The full extent of California's unsafe drinking water problem is difficult to grasp. Compliance information is best for community water systems with at least 15 connections. According to state data, in July 2018 more than 230 systems, serving roughly 357,000 people (0.9% of the population), had unsafe drinking water. More than 400 schools have their

own water systems, and 33 of them (serving 13,000 people) were also out of compliance. Recent efforts to test for lead in all schools' water supplies have found some contamination as well. Not much is known about water quality in the roughly 1,300 very small, county-regulated water systems (serving 5 to 14 connections) and the more than 350,000 domestic wells that serve one or several homes.

- **Groundwater contamination is the major issue.**
  Most systems with unsafe water rely on groundwater as a primary source. Various natural and human-caused contaminants are widespread in California's groundwater basins. Nitrate—mainly from nitrogen fertilizers and manure—is a problem in many areas. Naturally occurring contaminants such as arsenic and uranium also pose challenges. Additional contaminants continue to be identified and regulated.
- **Smaller systems are especially vulnerable.**
  Almost all systems that fail to meet safety standards are small—serving fewer than 3,300 people—and located in rural or unincorporated areas. Problems are particularly persistent in systems serving fewer than 500 people. Since groundwater needs little treatment unless there is a violation, these systems were developed cheaply, by drilling wells. But now they lack the technical, managerial, and financial resources to address contamination problems. Technology for removing contaminants is expensive to build and operate, and small systems do not have economies of scale. And water is often only one of many basic-service challenges facing these communities.
- **Problems are especially common in agricultural regions.**
  Roughly half of all noncompliant systems are in the San Joaquin Valley—the state's largest farming region and home to a third of California's disadvantaged communities. Most of these systems have been out of compliance for at least three years.

SOME COMMUNITIES FACE DRINKING WATER SHORTAGES DURING DROUGHT



SOURCES: Developed by the authors using data from the California Department of Water Resources (household water shortages) and the State Water Board (water systems).

NOTES: The map shows households reporting water supply outages on a state website (https://mydrywatersupply.water.ca.gov/report/publicpage) that tracks dry domestic wells and other outages from systems serving fewer than 15 connections, as well as 153 community water systems (with 15 connections or more) that sought emergency assistance. Just 15 of these serve more than 3,300 residents.

During droughts some small communities have unreliable water supplies

Some rural water systems and domestic wells are affected when farmers increase groundwater pumping during droughts, which can cause shallow wells to go dry and degrade their water quality. Some foothills communities that rely on aquifers with limited storage capacity are highly vulnerable to drought shortages, as are communities that depend on small, rain-fed surface water catchment areas.

- **The recent drought led to water shortages and dry wells.**
  At least 2,600 well-dependent households in California faced drinking water shortages in the recent drought. Additionally, more than 150 water systems applied for emergency state funding to address water supply and quality problems. Most households with dry wells were in the San Joaquin Valley (78%), where groundwater pumping for agriculture markedly increased.
- **Water shortages can persist after droughts end.**
  Local, state, and federal governments provided emergency funding to restore water supply during the drought. But these solutions were often stopgap—trucking in bottled water or delivering water to temporary holding tanks. Many affected wells are still dry, and some people still rely on temporary supplies. This is a recurring problem from past droughts, reflecting a need for longer-term solutions to prevent drinking water shortages in vulnerable communities.

Addressing these challenges requires a range of responses

Providing safe drinking water to poor communities affected by water contamination or shortages requires one of two things: water treatment or alternative sources of supply. The specific solutions could range from investment in a centralized treatment system to installation of decentralized treatment technology to consolidation with a larger neighboring system. Every scenario requires funding and partnerships.

- **Without reliable funding, many solutions are out of reach.**
  Recent bonds have made more funds available for capital investments, but the cost of water treatment systems' ongoing expenses can be a major hurdle. For example, the unincorporated community of Lanare in Fresno County struggled to deliver safe drinking water to its residents due to arsenic contamination. In 2007, the county built a $1.3 million treatment plant for them with help from state funds. But because Lanare lacked resources to operate the technology, the facility shut down after six months, leaving the community with a $100,000 debt. Avoiding such failures will require reliable, long-term funding to support small system operation and maintenance.
- **Consolidating water systems is a promising approach.**
  Often the best way to provide safe drinking water is by consolidating small water districts into larger ones. This can bring lower per unit costs and improved service. Consolidation can be either physical—where the systems are connected—or administrative—where they remain separate but share technical and managerial resources. It often involves difficult financial and technical issues, particularly when a smaller system needs costly upgrades to become compatible. A 2015 law gives the State Water Board authority to mandate mergers if necessary, and there were 13 mandatory consolidations as of summer 2018. Voluntary consolidations are also on the rise: there were 72 by summer 2018. Other bills propose new authorities to consolidate failing systems and to improve their management capacity.
- **Lack of reliable data impedes solutions.**
  An estimated 1 to 2 million Californians rely on domestic wells, yet there is no reliable data on the number of domestic wells, their location, their condition, or the population served. Data on the roughly 1,300 very small, county-regulated systems is also limited. This means key information is lacking on water availability and contamination for many residents—hindering effective planning and response.
- **Local planning and organization can help.**
  Much of the difficulty in implementing solutions reflects the limited capacity of small water systems to tackle problems on their own. But other local entities can help. For example, groundwater sustainability agencies established under the 2014 Sustainable Groundwater Management Act should develop programs to promptly mitigate dry wells caused by drought-related pumping. This model is already used effectively in Yuba County and parts of Kern County. Under new regulations in the San Joaquin Valley, agricultural and urban dischargers will soon need to form nitrate management zones, with responsibility for providing safe drinking water in their areas.

Looking ahead

There is growing awareness and action on the issue of providing safe and reliable drinking water to all Californians. This problem could be resolved in the near term with dependable funding and a clear state action plan.

Improve estimates of the population at risk from unsafe drinking water. Despite recent strides in understanding the extent of the safe drinking water challenge, there are still major data gaps and reporting problems. Developing more comprehensive and clearer metrics on quality is key to prioritizing actions and tracking progress. The state has made recent strides by digitizing well completion reports and making them publicly available. But much more can be done—for example, providing funding for well sampling and mandating reporting on well water quality when a property is sold.

Identify durable funding sources. PPIC estimates that solutions for small, poor communities would cost up to $160 million annually. Although state bonds and various federal programs support some infrastructure upgrades, more durable funding—including for operations and maintenance—is needed. One option is to establish new taxes or fees—recent bills proposed taxes on agricultural chemicals and dairies and voluntary surcharges on urban water bills. Another is to include ongoing expenses in bond-funded projects by appropriating money from the General Fund to pay for needed operation and maintenance.

Support cost-effective solutions. The State Water Board should continue to promote physical or administrative consolidation between small and large systems. Since private water companies play an important role, the California Public Utilities Commission should also emphasize reviewing consolidations. Developing affordable and effective ways to deliver safe water to communities that will need small-scale treatment—such as with remote monitoring systems—is also a priority.

Develop programs to mitigate the risk of dry drinking-water wells during droughts. In the recent drought, the state worked with counties and community groups to provide emergency supplies. State and local partners should use this experience to plan for the next drought. This includes identifying the communities at highest risk, connecting them to larger systems where feasible, and devising drought response programs for the others. Groundwater sustainability agencies should incorporate measures in their plans to mitigate the risk of wells running dry from local pumping. These agencies could also help create an inventory of domestic wells.

CONTACT A PPIC EXPERT

Ellen Hanak
hanak@ppic.org

Caitrin Chappelle
chappelle@ppic.org

Jelena Jezdimirovic
jezdimirovic@ppic.org

Brian Gray
gray@ppic.org

CONTACT THE RESEARCH NETWORK

Maura Allaire, mallaire@uci.edu
Sarge Green, sgreen@mail.fresnostate.edu
Thomas Harter, thharter@ucdavis.edu
Jay Lund, jrlund@ucdavis.edu
David Mitchell, mitchell@mcubed-econ.com
Debra Perrone, perrone@ucsb.edu

READ MORE

- CLIMATE CHANGE AND WATER
- THE COLORADO RIVER
- ENERGY AND WATER
- MANAGING DROUGHTS
- PAYING FOR WATER
- PREPARING FOR FLOODS
- PROTECTING HEADWATERS
- PROVIDING SAFE DRINKING WATER
- THE SACRAMENTO–SAN JOAQUIN DELTA
- STORING WATER
- WATER FOR CITIES
- WATER FOR THE ENVIRONMENT
- WATER FOR FARMS

This series is supported by the annual sponsors of the PPIC Water Policy Center.

The PPIC Water Policy Center spurs innovative water management solutions that support a healthy economy, environment, and society—now and for future generations.

The Public Policy Institute of California is dedicated to informing and improving public policy in California through independent, objective, nonpartisan research. We are a public charity. We do not take or support positions on any ballot measure or on any local, state, or federal legislation, nor do we endorse, support, or oppose any political parties or candidates for public office. Research publications reflect the views of the authors and do not necessarily reflect the views of our funders or of the staff, officers, advisory councils, or board of directors of the Public Policy Institute of California.

Public Policy Institute of California
500 Washington Street, Suite 600
San Francisco, CA 94111
T 415.291.4400 F 415.291.4401
PPIC.ORG/WATER

PPIC Sacramento Center
Senator Office Building
1121 L Street, Suite 801
Sacramento, CA 95814
T 916.440.1120 F 916.440.1121

PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA

PPIC

The Sacramento–San Joaquin Delta

PPIC WATER POLICY CENTER

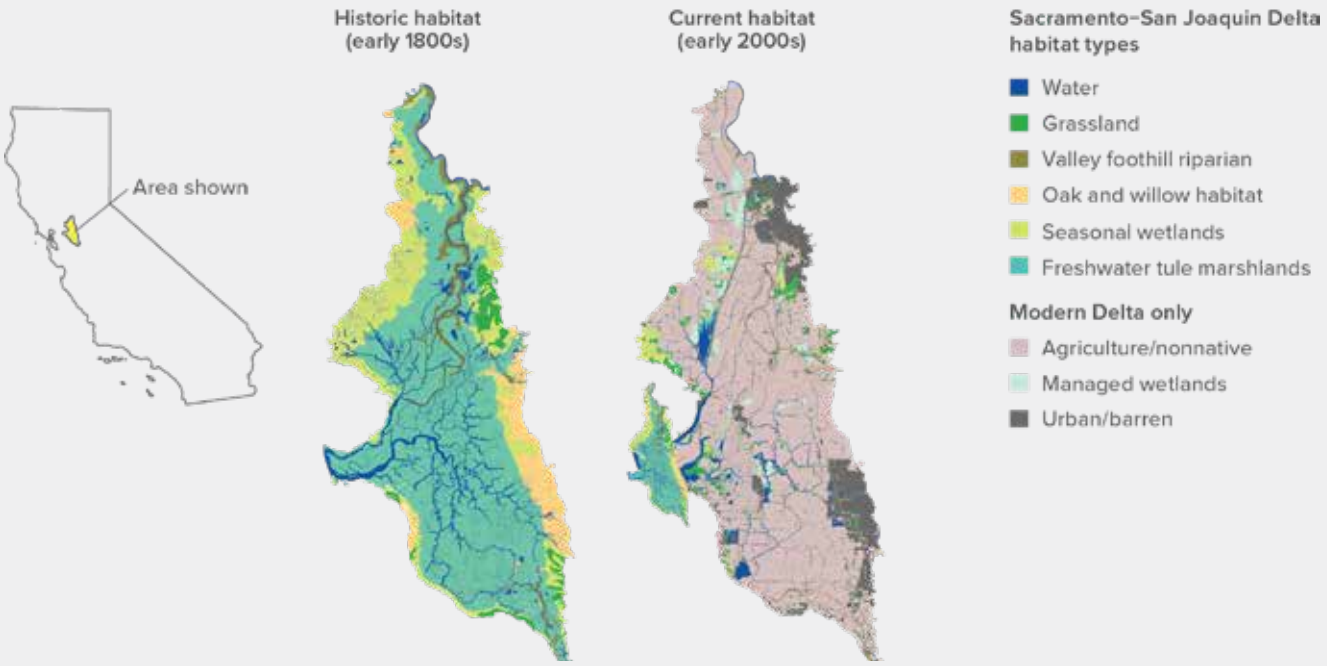
NOVEMBER 2018

The Delta is California's greatest water management challenge

The Sacramento–San Joaquin Delta is the terminus of California's largest watershed and a major water supply hub. The San Francisco Bay and Delta combined form the largest estuary on the US Pacific Coast. The southern Delta exports water to more than 25 million people and 3 million acres of irrigated farmland in the Bay Area, the San Joaquin Valley, and Southern California. This supply's reliability is declining. Levees that protect Delta farmland and keep saltwater at bay are at risk from rising sea levels, winter floods, sinking farmland, and earthquakes. Changes in the ecosystem harm native species, including salmon and smelt, which are now threatened with extinction. Efforts to protect these species put pressure on water supplies. The local Delta economy is also vulnerable to levee failure and declining water quality.

The Delta Reform Act of 2009 requires the state to manage the Delta for "coequal goals"—a more reliable water supply for California and improved Delta ecosystem health, plus protection of a unique and evolving cultural, recreational, natural, and agricultural place. Implementing this law has been controversial, but the economic, social, and environmental costs of failure would be high.

FARMING HAS RADICALLY CHANGED DELTA HABITAT



SOURCE: Adapted from A. Whipple et al., *Sacramento–San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process* (San Francisco Estuary Institute and the Aquatic Science Center, 2012).

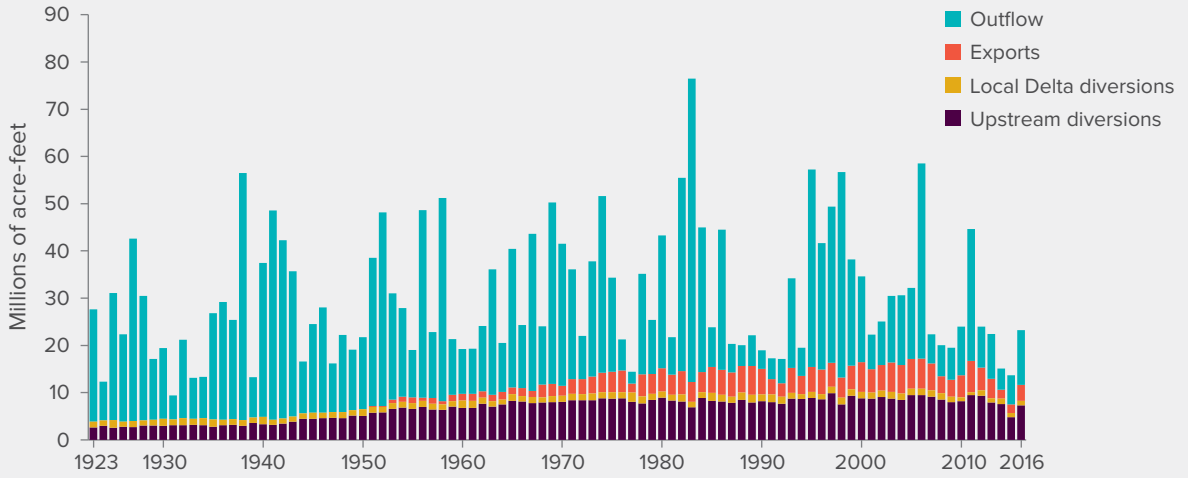
The Delta is changed and changing

Today's Delta is dramatically different from the one that existed before its lands, waterways, and upstream watersheds were developed. It continues to change in ways that make achieving the Delta Reform Act's goals difficult.

- **Land reclamation for farming transformed the Delta landscape.** Some 1,100 miles of levees have converted 700,000 acres of tidal marsh into "islands" of farmland. Farming caused peat-rich soils to oxidize and land to sink. Today, many islands are 10 to 25 feet below sea level. This causes drainage problems and increases pressure on levees, making flooding more likely and costly.

- **Water supply for farms and cities has reduced Delta outflow.**
  The Delta watershed is California's largest source of water for farms and urban areas. Since 2000, approximately one-third of total watershed runoff has been diverted upstream. In-Delta uses account for 4 percent, Central Valley Project and California State Water Project exports 18 percent. On average, 47 percent of runoff flows out of the Delta and into the San Francisco Bay—but this share varies greatly with the volume of precipitation.

DELTA OUTFLOWS HAVE DECLINED AS FARMS AND CITIES HAVE INCREASED THEIR WATER USE



SOURCES: Updated from Delta Vision Blue Ribbon Task Force, *Our Vision for the California Delta*, Figure 7b (2007). For 2007–16, estimates are from G. Gartrell et al., *A New Approach to Accounting for Environmental Water: Insights from the Sacramento–San Joaquin Delta* (PPIC, 2017).

- **Delta outflow serves many purposes.**
  Some outflow is required to repel seawater from the Delta so that water there remains fresh enough for exports and local cities and farms. Regulations to protect endangered fish create additional requirements. Since 2008—the most recent update to these regulations—42 percent of outflow was needed to maintain water quality for exports and local diversions, and another 21 percent for the ecosystem. The remaining 38 percent occurs principally during winter storms when flow exceeds the capacity of diversions. All outflow improves water quality and habitat throughout the estuary.
- **Ecosystem changes have harmed native species.**
  More than 35 native plants and animals that live in or pass through the Delta are now listed under endangered species acts. Multiple factors account for the decline of native fishes: loss of habitat, changes in flow volume and timing, changes in water quality, and unfavorable hatchery and fishing practices. In addition, many alien species have invaded the estuary, altering the environment and competing with or preying on native species.
- **Water supplies and the Delta economy are at increasing risk.**
  Climate change and other factors are reducing the reliability of water supplies and increasing flood risks for local communities. Warming and more variable precipitation change the timing and magnitude of flows into the Delta, increase salinity and harmful algal blooms, and make it more difficult to manage habitat for native species. This will increase pressure to release water from upstream reservoirs to protect Delta water quality. Changes in flood flows and rising sea levels will also increase risk of levee failure—threatening farms and communities, as well as water supply. Levees also risk failing from a large earthquake.

Balancing water supply and ecosystem goals is a major challenge

California has struggled for decades to find a balance between diverting Delta water and letting it flow through the estuary to support the ecosystem and meet state and federal regulations to protect endangered fishes. Since 2006, agencies that use Delta exports have been exploring a longer-term solution involving new water conveyance infrastructure and ecosystem improvements. California Water Fix (put forth in 2015) is the latest version of this proposal.

- **California Water Fix is ambitious ...**
  Large pumps in the southern Delta export water to the state's two major water delivery systems—the Central Valley Project and California State Water Project. California Water Fix would divert some of it from the Sacramento River north of the Delta into two tunnels, bypassing the Delta. California EcoRestore is an effort to meet permitting requirements for the projects. It aims to restore 30,000 acres of tidal marsh and floodplain habitat within and adjacent to the Delta by 2020.

- **... and involves many uncertainties.**
  Water Fix is likely to improve water supply quality and reliability and EcoRestore will create some habitat. But how future climatic, ecosystem, and regulatory conditions will affect program goals is uncertain. For example, it is unknown whether Water Fix or the proposed ecosystem improvements will substantially benefit native fish. Both programs require ongoing flexibility, experimentation, and refinement.

- **Costs are high, with no clear funding for the ecosystem ...**
  Urban and farm customers, not taxpayers, will foot the approximately $20 billion tunnel construction costs. EcoRestore's first phase will cost $300 million—also borne by water users. Recent state bonds provide important near-term support for ecosystems in the Delta and its watershed. But no clear mechanism exists to fund longer-term improvements and the science and monitoring needed to measure progress and steer future improvements.

- **... and new water quality regulations may impact both efforts.**
  The State Water Board will have to grant a permit for the new Water Fix facilities. The board is also updating flow and water quality standards for the Delta and its watershed, which could increase the outflow required to support the ecosystem. Both proceedings may affect the construction and operation of Water Fix and the implementation of EcoRestore.

Improving Delta levees is another big challenge

The Delta's levees support the current water export system; critical roads, pipelines, and power lines; and the local economy. The high cost of upgrading levees and the low land values of areas they protect ~~-co~~upled with limited state and federal funding create tough choices on how and where to invest.

- **The region faces a sizable levee funding gap.**
  According to recent state estimates, the five Delta counties need more than $12 billion in flood investments. This includes levees in the inner Delta, where few people live, and urban areas with large vulnerable populations such as West Sacramento and Stockton. The costs of upgrading many of the agricultural levees exceed the economic value of the land they protect, and only some levees are needed to keep Delta waters fresh.

- **Limited state funds should be prioritized.**
  State bonds approved in 2006 dedicated nearly $600 million to Delta levees, and more recent bonds earmark another $350 million. In 2017 the Delta Stewardship Council set priorities for investing state funds in these levees. The highest priorities will be levees that protect urban areas, critical infrastructure, and ecosystem restoration projects or areas with high potential for habitat restoration.

Looking ahead

If Californians put off difficult decisions regarding the Delta, the region's growing population, rising and warming waters, and changing ecosystem will make it even harder to find solutions. Five areas need immediate attention.

Make a strategic decision on water supplies. The state must decide whether to move forward with California Water Fix or prepare for reductions in Delta water export reliability. The latter alternative would force cities in the Bay Area and Southern California to turn to more expensive water sources. In the San Joaquin Valley, the no Water Fix approach would reduce farming and make it harder to manage groundwater sustainably. And the value of new state investments in water storage capacity would diminish without the ability to reliably convey water across the Delta.

Ensure robust scientific support. Scientific and technical support for managing the Delta has been underfunded and poorly organized. To improve decision making and reduce controversy and litigation, the state and federal governments

should make substantial, sustained investments in more integrated scientific work, as outlined in the new Delta Science Plan. More complete water accounting is also needed to support management and inform policy.

Manage the Delta as an ecosystem. To improve environmental outcomes, the state and federal governments should shift from a focus on managing outflows for endangered fish species to an ecosystem-based approach. This entails managing river flows, tidal flows, and landscapes together to improve habitat for a broad array of fish and wildlife. Efforts should be concentrated in the northern Delta and Suisun Marsh, and they should include strategies for reducing harmful algal blooms. An ecosystem water budget for the Delta, which would allocate a portion of water to the ecosystem, could enable more flexible and effective management.

Implement a priority-based levee improvement program. The Delta Plan's priorities for levee investments are likely to yield the greatest reduction in economic and environmental risk, while using state funds most efficiently. The Department of Water Resources should follow these priorities in allocating state resources.

Incorporate long-term change into all aspects of planning. The state should prepare for significant changes in the Delta from rising sea level, climate warming, declining sediment supply, invasions of new species, and other changes.

CONTACT A PPIC EXPERT

Jeffrey Mount
mount@ppic.org

Caitrin Chappelle
chappelle@ppic.org

Brian Gray
gray@ppic.org

Ellen Hanak
hanak@ppic.org

CONTACT THE RESEARCH NETWORK

Greg Gartrell, greggartrell@ix.netcom.com
Wim Kimmerer, kimmerer@sfsu.edu
Jay Lund, jrlund@ucdavis.edu
Peter Moyle, pbmoyle@ucdavis.edu

READ MORE

- CLIMATE CHANGE AND WATER
- THE COLORADO RIVER
- ENERGY AND WATER
- MANAGING DROUGHTS
- PAYING FOR WATER
- PREPARING FOR FLOODS
- PROTECTING HEADWATERS
- PROVIDING SAFE DRINKING WATER
- THE SACRAMENTO–SAN JOAQUIN DELTA
- STORING WATER
- WATER FOR CITIES
- WATER FOR THE ENVIRONMENT
- WATER FOR FARMS

This series is supported by the annual sponsors of the PPIC Water Policy Center.

The PPIC Water Policy Center spurs innovative water management solutions that support a healthy economy, environment, and society—now and for future generations.

The Public Policy Institute of California is dedicated to informing and improving public policy in California through independent, objective, nonpartisan research. We are a public charity. We do not take or support positions on any ballot measure or on any local, state, or federal legislation, nor do we endorse, support, or oppose any political parties or candidates for public office. Research publications reflect the views of the authors and do not necessarily reflect the views of our funders or of the staff, officers, advisory councils, or board of directors of the Public Policy Institute of California.

Public Policy Institute of California
500 Washington Street, Suite 600
San Francisco, CA 94111
T 415.291.4400 F 415.291.4401
PPIC.ORG/WATER

PPIC Sacramento Center
Senator Office Building
1121 L Street, Suite 801
Sacramento, CA 95814
T 916.440.1120 F 916.440.1121

PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA

PPIC

Storing Water

PPIC WATER POLICY CENTER

NOVEMBER 2018

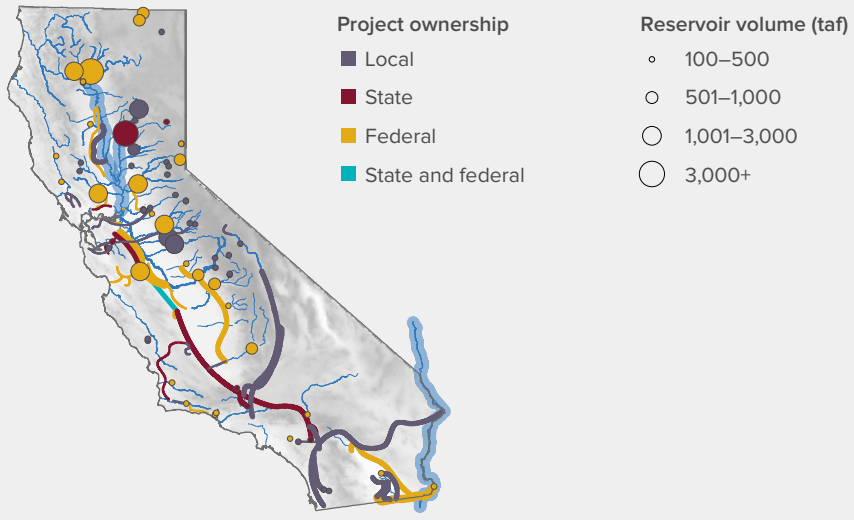
Storage is essential for managing California's water

California's "water grid" is a vast interconnected surface and groundwater storage network linking major water demand centers via rivers and aqueducts. Water stored during wet winter and spring months provides supplies for dry summers and frequent droughts. It is also used for recreation and hydropower, and to mitigate harmful effects dams have on river and wetland ecosystems. During large storms, storage also reduces downstream flood damage.

Water storage in California takes many forms. As much as a third of all supply comes from snowpack, which releases water during spring and summer when demand is highest. Water stored in soils supports plant growth and helps regulate storm runoff. Nearly 1,500 surface reservoirs can store up to 43 million acre-feet (maf)—a year's supply for farms and cities. The state's 517 groundwater basins hold considerably more water than these reservoirs. And many aquifers could store more water because decades of groundwater depletion have created unused space.

Managing water storage is complex. Its competing priorities must be balanced. These include flood protection and water supply, reducing environmental harm from dams, addressing long-term excess pumping and pollution of groundwater, maintaining and updating infrastructure, and adapting to a smaller snowpack and more intense storms as the climate warms. Groundwater users across California have begun implementing the 2014 Sustainable Groundwater Management Act (SGMA), the first statewide effort to manage groundwater. And $2.7 billion in bond funds will support water storage projects under 2014's Proposition 1. But major challenges remain.

CALIFORNIA'S "WATER GRID" IS A STATEWIDE NETWORK OF STORAGE AND CONVEYANCE FACILITIES



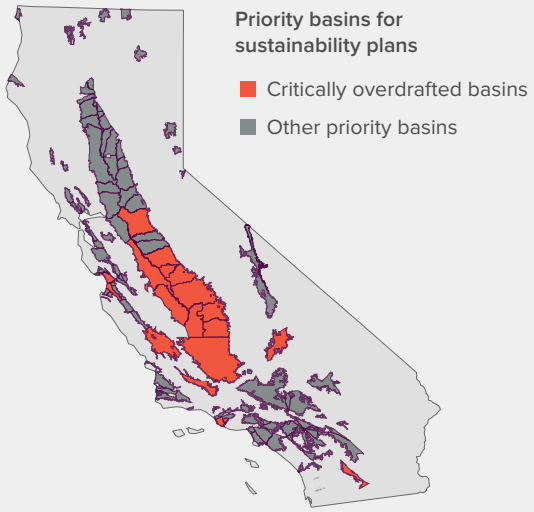
SOURCE: Developed by the authors using information from the California Department of Water Resources.

NOTES: "Taf" is thousands of acre-feet. The map shows 62 surface reservoirs with storage capacity over 100 taf, scaled to size. Their combined capacity is 36.5 million acre-feet (maf). The lines show rivers in blue and built conveyance facilities (canals, aqueducts) colored by ownership. Not shown are more than 1,400 smaller reservoirs (with a total capacity of less than 7 maf) and the state's 517 groundwater basins.

Groundwater is California's most important drought reserve

Groundwater is California's largest source of storage. In non-drought years, it supplies about a third of the water for cities and farms, and more in some regions. During severe droughts, groundwater provides more than half of water used statewide. Although aquifers fill more slowly than surface reservoirs, they can be replenished.

BASINS ACROSS CALIFORNIA MUST COMPLY WITH THE SUSTAINABLE GROUNDWATER MANAGEMENT ACT



SOURCE: California Department of Water Resources, California Statewide Groundwater Elevation Monitoring Program.

NOTES: Under SGMA, groundwater users in critically overdrafted basins must adopt sustainability plans by 2020 and attain sustainable management within 20 years; for other priority basins, plans must be adopted by 2022. In all, 127 basins, accounting for 96 percent of annual groundwater pumping, are considered priority basins that must comply within this time frame. Some additional basins may need to comply as a result of a basin prioritization update now under way.

- **Unregulated pumping causes multiple problems.**
Until 2014, the state regulated groundwater loosely. As a result, many basins are in overdraft (when excess pumping causes long-term declines). Low levels increase energy costs of pumping, dry out shallower wells, reduce flows to rivers and wetlands, allow seawater intrusion in coastal areas, and cause land to sink (or "subside"), which damages water canals and other infrastructure.

- **Many cities have effective groundwater management programs.**
Many cities in Southern California and the San Jose area resolved problems from past overdraft by regulating, metering, and charging for pumping. Local management agencies replenish basins with local rainfall, water imported from distant rivers, and recycled wastewater and stormwater. Recharge methods include moving water into ponds, injecting it into wells, and allowing it to seep through permeable pavement and rain gardens.

- **Limited groundwater oversight in agricultural areas has fueled overdraft.**
The San Joaquin Valley's overdraft averages about 2 maf annually, and problems are also acute in the Central Coast. New challenges to sustainable groundwater management are arising. Many farms are shifting to orchards and vineyards, which are costly to fallow and often rely on groundwater to survive droughts. Meanwhile, as farmers adopt more efficient technology, recharge from irrigation is declining.

- **Poor groundwater quality is also a problem.**
Many basins have problems with arsenic and other naturally occurring contaminants that can pose health problems. In some urban areas, industrial pollutants limit groundwater for drinking. In farming regions, shallow groundwater is often polluted by high levels of nitrate from fertilizers and manure. Salt accumulation is a growing problem for farming in the San Joaquin Valley and coastal areas. Treatment is an option for large urban systems, but it is usually too costly for small communities and farms. Recharging basins with clean water can improve quality.

- **The Sustainable Groundwater Management Act holds promise.**
SGMA requires water users in the most stressed basins to develop groundwater sustainability plans by 2020 and bring their basins into balance by 2040. More than 250 groundwater sustainability agencies are developing plans, and the law authorizes them to measure use and charge fees for pumping and to cover recharge project costs. The State Water Board can intervene if it deems local efforts inadequate, or if local authorities request assistance.

Surface reservoirs provide California's most flexible storage

California's surface reservoirs can be filled and emptied quickly to meet demands for water supply, aquatic habitat, flood control, recreation, and hydropower.

- **Surface storage has limited value during long droughts.**
Reservoirs store water for seasonal uses and reserve some water for dry years. Extended drought depletes these reserves. At the height of the 2012–16 drought, most large reservoirs were at or near record lows.

- **Flood storage competes with water supply storage.**
Many large, multipurpose reservoirs release water in fall and winter to free up space for winter flood flows. Under US Army Corps of Engineers rules, this flood reserve cannot be refilled until late winter or spring, when the flood season has passed. If the winter is dry, reservoirs won't fill up.

- **Dams disrupt river ecosystems.**
  Dams limit access to fish spawning habitat and alter natural flow patterns, harming native fish, plants, and animals. Reservoir releases can sometimes mitigate these impacts—for example, by releasing cold water for salmon. Some dams are being removed to restore more natural flows and give fish access to better upstream habitats. Plans are under way to remove four aging hydropower dams on the Klamath River.
- **Climate change will complicate reservoir operations.**
  Climate pressures include rising temperatures, declining snowfall, more intense storms, and more extreme wet and dry years. Increased winter runoff will make it harder to manage reservoirs for flood control and store enough water for other purposes. Rising temperatures will also make it harder to provide cold water for fish.
- **New surface storage may be costly relative to its water supply benefits.**
  New storage could improve water system flexibility. But the average volume of new water from these facilities is small, and costs are high. Four projects deemed eligible for state matching grants under Proposition 1 would expand statewide reservoir *capacity* by about 3.3 million acre-feet, but they would raise annual average *supply* by only 760,000 acre-feet, or 2 percent of annual farm and city use. Their combined cost would be nearly $10 billion.

Managing California's storage resources as a system can boost benefits

Many reservoirs have their own set of rules and are operated by an array of agencies. And surface reservoirs aren't currently operated to maximize groundwater recharge. Modernizing operations and integrating management of above- and belowground storage can boost usable supplies, improve quality, and help lessen the impacts of climate change.

- **Groundwater and surface storage work better together.**
  Some storm runoff and water in surface reservoirs can be moved to groundwater basins. Such joint management of groundwater and surface water—known as conjunctive use—can boost resilience to droughts. It may also ease the growing conflict between using reservoirs for flood protection and water storage as winter runoff increases.
- **Conveyance is often a bigger bottleneck than storage capacity.**
  Without investments to improve water conveyance reliability across the Sacramento–San Joaquin Delta, significantly expanding groundwater storage in the southern half of California—where basins are most depleted—will be hard. Subsidence has also reduced the capacity of the Friant-Kern Canal and the California Aqueduct. Some conjunctive use projects also need local conveyance investments.
- **Institutional bottlenecks are also an issue.**
  More flexibility in reservoir operations would increase the benefits of conjunctive use, but this requires lengthy federal and state agency approvals. Better local aquifer management is also needed. And the state should clarify the rules on water available for recharge.
- **Better flood management can help …**
  Setting back levees to give rivers more room to move into their floodplains can improve flood protection and help store some floodwaters. This practice can also recharge local aquifers, improve habitat, and preserve open space for farming and recreation. Spreading excess winter flows on farmland is also promising but requires careful consideration of water quality.
- **… and so can better watershed management.**
  Forest management in upper watersheds can increase available streamflow by as much as 5 percent by decreasing water used by plants and improving storage in snowpack and soils. Yet implementing these changes on millions of mountain acres is a challenge.

Looking ahead

California has made good progress on addressing storage challenges, but much hard work lies ahead.

Update aging infrastructure. California's water grid—including important aqueducts that help recharge groundwater, deliver surface water, and manage floods—is aging and needs repair. The 2017 Oroville Dam spillway failures prompted new safety laws and reviews of existing dams, but more should be done to improve safety and prepare the system for a changing climate. Conveyance improvements to support groundwater storage are also a priority.

Promote flexibility and integrate operations. Operational changes are needed to make the system more flexible in light of a more volatile climate. Priorities include modernizing and integrating operations of multipurpose reservoirs to ensure they work together as an integrated water supply and flood management system, and increasing the flexibility of reservoir operation rules to allow more efficient use of above- and belowground storage.

Ensure effective groundwater sustainability plans. Delay will encourage more overdraft and make future choices harder. State bonds provide resources for local planning, and 2015 legislation makes it easier for agencies to allocate pumping rights. One urgent state priority is to clarify water available for groundwater recharge.

Protect and restore groundwater quality. Controlling new sources of pollution and cleaning up contaminated basins can improve groundwater storage. Meanwhile, safe drinking water is urgently needed in rural, groundwater-dependent communities. Bond funds are available for both purposes, but reliable funding is needed for ongoing costs of safe drinking water programs in disadvantaged communities.

CONTACT A PPIC EXPERT

Alvar Escriva-Bou
escriva@ppic.org

Brian Gray
gray@ppic.org

Ellen Hanak
hanak@ppic.org

Jeffrey Mount
mount@ppic.org

CONTACT THE RESEARCH NETWORK

Andrew Fisher, afisher@ucsc.edu
Graham Fogg, gefogg@ucdavis.edu
Jason Gurdak, jgurdak@sfsu.edu
Thomas Harter, thharter@ucdavis.edu
Jay Lund, jrlund@ucdavis.edu
Debra Perrone, perrone@ucsb.edu

READ MORE

- CLIMATE CHANGE AND WATER
- THE COLORADO RIVER
- ENERGY AND WATER
- MANAGING DROUGHTS
- PAYING FOR WATER
- PREPARING FOR FLOODS
- PROTECTING HEADWATERS
- PROVIDING SAFE DRINKING WATER
- THE SACRAMENTO–SAN JOAQUIN DELTA
- STORING WATER
- WATER FOR CITIES
- WATER FOR THE ENVIRONMENT
- WATER FOR FARMS

This series is supported by the annual sponsors of the PPIC Water Policy Center.

The PPIC Water Policy Center spurs innovative water management solutions that support a healthy economy, environment, and society—now and for future generations.

The Public Policy Institute of California is dedicated to informing and improving public policy in California through independent, objective, nonpartisan research. We are a public charity. We do not take or support positions on any ballot measure or on any local, state, or federal legislation, nor do we endorse, support, or oppose any political parties or candidates for public office. Research publications reflect the views of the authors and do not necessarily reflect the views of our funders or of the staff, officers, advisory councils, or board of directors of the Public Policy Institute of California.

Public Policy Institute of California
500 Washington Street, Suite 600
San Francisco, CA 94111
T 415.291.4400 F 415.291.4401
PPIC.ORG/WATER

PPIC Sacramento Center
Senator Office Building
1121 L Street, Suite 801
Sacramento, CA 95814
T 916.440.1120 F 916.440.1121

PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA

PPIC

Water for Cities

PPIC WATER POLICY CENTER

NOVEMBER 2018

Despite progress, California's cities face water management challenges

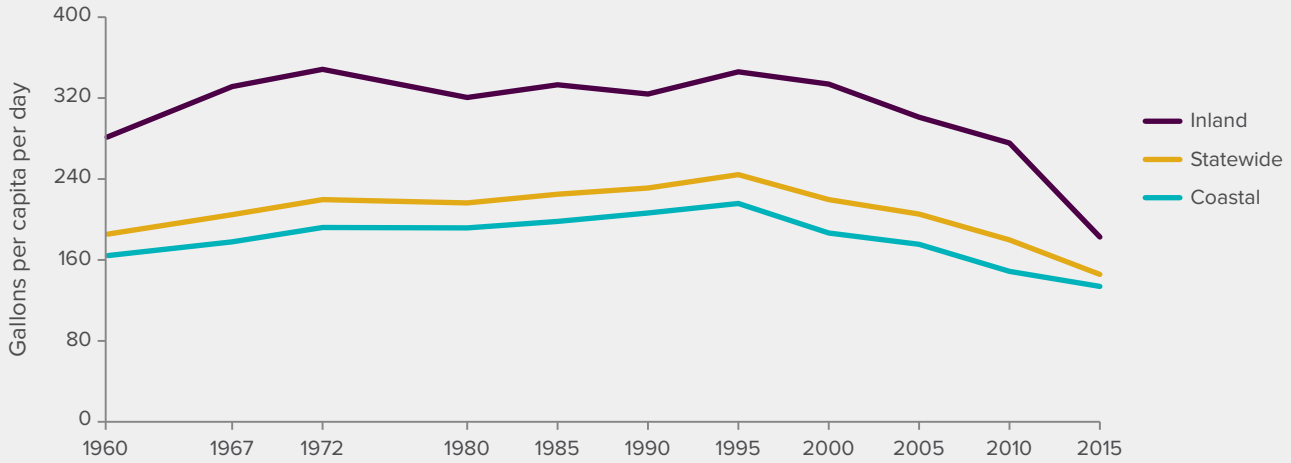
The water systems that supply California's households, businesses, and industries are vast and complex. More than 400 urban retail utilities—each serving at least 3,000 homes and businesses—supply more than 90 percent of the state's residents. Several dozen wholesale utilities deliver water to about half of these retailers; the largest wholesaler covers 19 million residents across six Southern California counties. Nearly 2,500 smaller utilities serve rural and some suburban communities. Most utilities are public agencies with locally elected governing boards. Privately owned utilities serve about 16 percent of Californians.

Large utilities can spread fixed infrastructure costs over a wide customer base. They often have several water sources and extensive technical expertise. Smaller utilities are often geographically isolated, and new investments incur high costs per customer. They usually rely on local groundwater and have limited in-house resources.

Decades of investments in conservation, storage, new supplies, and interconnections for sharing water have improved the large urban systems' drought resilience. Some small, isolated systems have not fared as well. Water utilities of all sizes experienced fiscal problems from reduced sales during the 2012–16 drought.

Large and small utilities face water supply and quality challenges. Many large utilities rely on imported water from the Sacramento–San Joaquin Delta and other distant locations. Infrastructure weaknesses and claims on water for the environment are making these sources increasingly vulnerable. Some utilities that rely on groundwater must address contamination, and many will face pumping limits under the 2014 Sustainable Groundwater Management Act. Utilities also need to prepare for a growing population and the likelihood that climate change will bring more severe droughts.

PER CAPITA URBAN WATER USE HAS BEEN FALLING AND FELL STEEPLY DURING THE LATEST DROUGHT



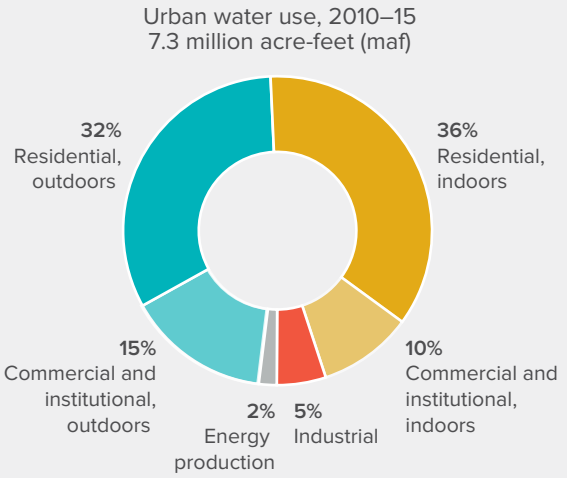
SOURCE: Author calculations using data from the California Department of Water Resources, *California Water Plan Update* (various years).

NOTES: The figure shows "applied" water delivered to homes and businesses. "Net" water use—i.e., the volume consumed by people or plants, embodied in manufactured goods, evaporated, or discharged to saline waters—is lower. The totals exclude water used by power plants and groundwater recharge projects and water lost during conveyance. Except for 2015 (a severe drought year), the estimates are for normal or "normalized" rainfall years (i.e., adjusted to levels that would have been used in a year of normal rainfall). Estimates are for water years (October to September). Inland areas tend to have higher per capita use because of higher temperatures and larger landscaped areas.

Water use in cities is changing

Following decades of increases, total urban water use began to flatten in the mid-1990s, reflecting per capita declines. Cities now use about 10 percent of California's available water, farms 40 percent. The remaining half is categorized as environmental, such as flows in wild and scenic rivers along the North Coast.

LANDSCAPING IS ROUGHLY HALF OF TOTAL URBAN WATER USE



SOURCE: California Department of Water Resources.

NOTES: The figure shows the average "applied" urban water use, as defined in the notes to the preceding figure. "Net" urban water use (also defined above) was lower (5 maf). Commercial and institutional outdoor use includes official estimates for "large landscapes" (parks, golf courses, cemeteries, etc.) and one-third of the total estimate for commercial and institutional demand, which includes other outdoor water use.

- **Per capita water use has been falling since the mid-1990s ...**

In 2010, average urban daily water use was 178 gallons per capita, down from 244 in 1995. The adoption of plumbing fixtures and household appliances that use less water has been a major factor. Since the early 1990s, water-saving toilets and showerheads have been required in new construction and encouraged in older buildings through rebate programs.

- **... and communities significantly cut use during the latest drought.**

Urban areas cut water use in response to voluntary local programs and a statewide conservation mandate that ran from April 2015 to June 2016. Water use declined by nearly 25 percent, bringing average per capita use down to 130 gallons per day. It is rebounding from drought levels, but it remains substantially lower than before the drought.

- **The urban economy has become less dependent on water-intensive activities.**

Many water-intensive industries have moved out of state, and manufacturing now uses only 5 percent of urban water, down from 8 percent in 1990. Overall, businesses have been reducing water use while continuing to grow. In 2014, cities generated more than three times the economic value per gallon than in 1967, measured by output of goods and services in inflation-adjusted dollars.

- **Landscape irrigation is the largest urban water use.**
  Outdoor watering accounts for roughly half of statewide urban water use and more in inland areas, where summers are hotter and yards tend to be larger. Savings can come from installing more efficient irrigation systems and replacing lawns with drought-tolerant landscaping. Many conservation efforts during the latest drought focused on reducing landscape watering.

Cities need to manage for reliability, cost, and financial stability

Utilities are pursuing a range of strategies to manage demand and diversify water sources. These investments are mainly funded by revenues from local water sales.

- **Pricing is important for managing demand ...**
  Water prices provide fundamental incentives for conservation. Providing information on bills about how a household's use compares with similar homes can also incentivize savings. Bills should also be easy to understand.
- **... and pricing must keep utilities fiscally strong.**
  To avoid financial problems, rate structures should recover costs when water sales fall or when supply costs increase. This was a challenge during the latest drought, when sales fell and costs rose, leaving many utilities in the red.
- **Improving efficiency has benefits, but makes it harder to cut use quickly during droughts.**
  Temporary reductions in outdoor water use generated much of the water savings during the latest drought. New state policy will increase indoor and outdoor efficiency over the long term. This could make it more difficult and costly to reduce urban water use during future droughts. To stay resilient, utilities should store some of the long-term water savings as a drought reserve rather than using all of it to accommodate growth.
- **Many utilities are developing local supplies.**
  Some investments can be relatively low cost, such as recharging local groundwater basins with surface water. Alternative supplies such as recycled wastewater and desalinated water are generally more expensive than traditional supplies, but they can boost reliability during droughts.

- **Imported supplies remain critical for most cities.**
  Cities in the San Francisco Bay Area and Southern California get more than half of their water from other regions. Some of this—notably imports from the Delta—will require major new investments to remain reliable. Cities must weigh the costs and reliability of imported versus local supplies in the context of diversifying their water sources.
- **Water trading is a growing supply source.**
  In several regions, cities have long-term agreements to lease water from farmers. More than 10 percent of Southern California urban supplies comes from such trades. Storing water in rural groundwater basins is also on the rise. Water leases and exchanges with neighboring cities were very valuable during the recent drought—though some utilities faced regulatory and infrastructure hurdles.
- **Proposition 218 poses challenges for urban water management.**
  This constitutional change, adopted by voters in 1996, specifies that some rates and fees cannot exceed the cost of providing a service to individual customers. Some courts have ruled that conservation-oriented rates (called tiered or budget-based rates) may violate this requirement. This may also constrain drought-responsive pricing, such as charging higher prices when supplies become scarce and water use goes down. Proposition 218 also restricts using water rates to fund lifeline programs, which help low-income customers. And it limits larger communities' ability to share the cost of annexing smaller systems—a promising way to ensure safe drinking water in some poor communities.
- **New state drought planning policies will increase local and state coordination.**
  One driver for the state's mandated conservation during the 2012–16 drought was lack of information on local drought plans and responses. This may have resulted in water savings beyond what was locally needed and undermined local programs to strengthen supplies. New state policy requires utilities to report annually on potential supply shortages and responses. Better state/local coordination may reduce the need for another statewide mandate.

Looking ahead

Although local utilities bear most frontline responsibility for providing safe and reliable water, state action is also important to support local efforts. The following areas address top concerns.

Consider a changing climate when planning for future droughts. New state policy requires utilities to assess the reliability of supplies in the event of a five-year drought. Instead of relying on past hydrology to simulate drought scenarios, utilities should evaluate impacts from longer, warmer droughts than 2012–16.

Evaluate local solutions in a regional context. Many opportunities exist for local utilities to improve how their systems work together. This includes investing in regional interconnections and sharing water. As utilities develop local sources such as recycled water, they should also consider regional impacts. For instance, because water recycling captures discharges, it can reduce streamflows that support ecosystems or supply communities downstream. Additionally, programs to encourage indoor water savings should consider the impact of reduced wastewater flows on wastewater management.

Develop flexible and robust water pricing. Utilities need to hone their rate structures to provide incentives for efficiency while maintaining their finances—for instance, by charging higher prices per gallon during drought.

Encourage more outdoor conservation. Low-water landscaping has the greatest potential for urban water savings. New state outdoor water use standards will promote this shift. Turf replacement programs set important examples, but they cost too much for widespread use. Making significant progress will require a mix of new technologies, economic incentives, building codes, and consumer awareness campaigns.

Keep an eye on costs. Utilities must weigh the costs and reliability of different supply options. And prices should be efficacious, fair, and affordable for low-income households.

Increase public education. Public concern about water rises sharply during drought and wanes somewhat once it abates. Wide-reaching educational programs can both encourage Californians to use less water *and* explain how higher prices help maintain resilient local systems. Information on the safety of highly treated recycled water is critical.

Guide the courts on water management priorities. Legislation can guide courts in interpreting Proposition 218's cost-recovery requirements. The legislature should emphasize supply diversification, conservation, and support for low-income customers to respond to growing water scarcity and affordability concerns.

Use new bond funds for cutting-edge actions. Recent bonds authorized significant new spending on urban water projects including conservation, recycling, desalination, and stormwater capture. The state should ensure these funds go to innovative projects rather than simply substituting for money urban utilities could raise from water bills.

CONTACT A PPIC EXPERT

Ellen Hanak
hanak@ppic.org

Alvar Escriva-Bou
escriva@ppic.org

Henry McCann
mccann@ppic.org

CONTACT THE RESEARCH NETWORK

Newsha Ajami, newsha@stanford.edu
Ken Baerenklau, ken.baerenklau@ucr.edu
David Jassby, jassby@ucla.edu
Jay Lund, jrlund@ucdavis.edu
David Mitchell, mitchell@mcubed-econ.com
Kurt Schwabe, kurt.schwabe@ucr.edu
David Sedlak, sedlak@berkeley.edu
Casey Wichman, wichman@rff.org

READ MORE

- CLIMATE CHANGE AND WATER
- THE COLORADO RIVER
- ENERGY AND WATER
- MANAGING DROUGHTS
- PAYING FOR WATER
- PREPARING FOR FLOODS
- PROTECTING HEADWATERS
- PROVIDING SAFE DRINKING WATER
- THE SACRAMENTO–SAN JOAQUIN DELTA
- STORING WATER
- WATER FOR CITIES
- WATER FOR THE ENVIRONMENT
- WATER FOR FARMS

This series is supported by the annual sponsors of the PPIC Water Policy Center.

The PPIC Water Policy Center spurs innovative water management solutions that support a healthy economy, environment, and society—now and for future generations.

The Public Policy Institute of California is dedicated to informing and improving public policy in California through independent, objective, nonpartisan research. We are a public charity. We do not take or support positions on any ballot measure or on any local, state, or federal legislation, nor do we endorse, support, or oppose any political parties or candidates for public office. Research publications reflect the views of the authors and do not necessarily reflect the views of our funders or of the staff, officers, advisory councils, or board of directors of the Public Policy Institute of California.

Public Policy Institute of California
500 Washington Street, Suite 600
San Francisco, CA 94111
T 415.291.4400 F 415.291.4401
PPIC.ORG/WATER

PPIC Sacramento Center
Senator Office Building
1121 L Street, Suite 801
Sacramento, CA 95814
T 916.440.1120 F 916.440.1121

PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA

PPIC

Water for the Environment

PPIC WATER POLICY CENTER

NOVEMBER 2018

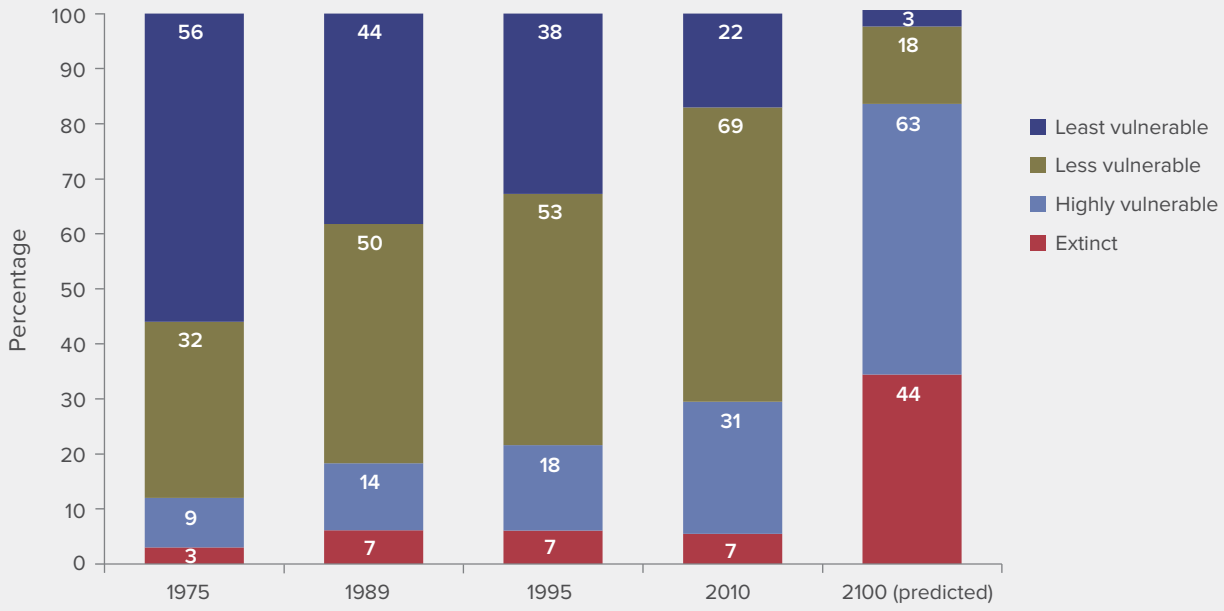
Water is vital for California's diverse and troubled ecosystems

California's diverse landscape and climate make it a biodiversity hot spot—home to more endemic plants and animals than any other state. It is also an important stop on the Pacific Flyway, providing habitat for millions of migratory birds. The state's rivers, lakes, wetlands, and estuaries support this rich biodiversity.

Dramatic changes in water and land use since statehood in 1850 have transformed California's freshwater landscape. Today, nearly 1,500 dams cut off most spawning habitat for salmon and steelhead. About 95 percent of the native vegetation that once lined Central Valley rivers and creeks has been eliminated, along with wetlands that hosted migratory waterfowl. Farms and cities use about half of the state's available water, and they discharge harmful pollutants into waterways.

Four decades after the enactment of major state and federal environmental laws, California's freshwater biodiversity remains at risk. Populations of native freshwater fishes—key indicators of aquatic ecosystem health—have dramatically declined. A quarter of these species are listed as threatened or endangered under state or federal endangered species acts, and many others are vulnerable. For both economic and social reasons, California must improve its stewardship of freshwater ecosystems. Climate change and population growth bring a great challenge: to strike a balance between improving ecosystem health and providing reliable water supplies, flood control, and hydropower.

CALIFORNIA'S NATIVE FRESHWATER FISHES ARE AT RISK



SOURCES: R. M. Quiñones and P. B. Moyle, "California's Freshwater Fishes: Status and Management," *FiSHMED Fishes in Mediterranean Environments* (2015). P. B. Moyle, J. D. Kiernan, P. K. Crain, and R. M. Quiñones, "Climate Change Vulnerability of Native and Alien Freshwater Fishes of California: A Systematic Assessment Approach," *PLoS One* 8 (5) (2013), doi:10.1371/journal.pone.0063883.

NOTES: The figure shows freshwater native fish status based on field surveys. Bars display the number of species for which information for evaluation was available in the specified time period. Predicted status in 2100 assumes continuation of current trends, with added stress from climate change. Extinct means no longer found in California; highly vulnerable means high risk of extinction by 2100; less vulnerable means lower risk of extinction than the previous group; least vulnerable means very low risk of extinction.

Environmental water use is not well understood

Water the state counts as "environmental" serves a variety of purposes—including supporting freshwater ecosystems and maintaining water quality for farm and urban uses. Although most of it is not in direct competition with other uses, a growing amount goes toward protecting endangered species. This causes controversy because it can reduce water available for other purposes. A better understanding of environmental water use can inform future management decisions.

- **Water that stays in rivers, streams, and wetlands is assigned to the environment.**
  There are four broad types of environmental water: water that flows in rivers protected as "wild and scenic" under federal and state laws, water needed to maintain aquatic habitat within streams, water that supports wetlands for migratory birds, and water needed to manage salinity and fish habitat in the Sacramento–San Joaquin Delta. On average, water categorized as environmental accounts for half of state use; farms (40%) and cities (10%) make up the other half. But the share of environmental water use varies widely, from 65 percent in the wettest years to 35 percent in the driest.
- **Most environmental water does not affect other uses.**
  Half of all environmental water occurs in remote North Coast rivers, with little competition for use. In the rest of California, where water is shared by all three sectors, environmental water represents about 33 percent of all uses on average (versus 53% for farms and 14% for cities). In these regions, some water dedicated to the environment may limit water available for other uses.
- **Environmental water often achieves multiple benefits.**
  Water quality and flow standards that protect fish and other species also maintain quality for human uses. This is especially true in the Delta, where freshwater outflows are required to maintain water quality for farms and cities as well as fish. Water that flows in wild and scenic rivers provides recreational opportunities. And in the Central Valley, downstream reservoirs then capture it for distribution to farms and cities.
- **Droughts heighten conflict over environmental water allocations.**
  A common misperception is that the environment receives a disproportionate share of water during drought. Because the environment relies principally on surface water, it actually experiences larger reductions during droughts than farms and cities, which can often pump additional groundwater when rivers are low. In some places, this extra pumping further reduces streamflows and harms fish. Droughts also put pressure on regulators to relax environmental standards to boost supplies. In 2014 and 2015, for example, the state approved multiple requests to reduce environmental flows and relax salinity standards in the Delta to increase water exports for farms and cities.

California needs to use environmental water more efficiently

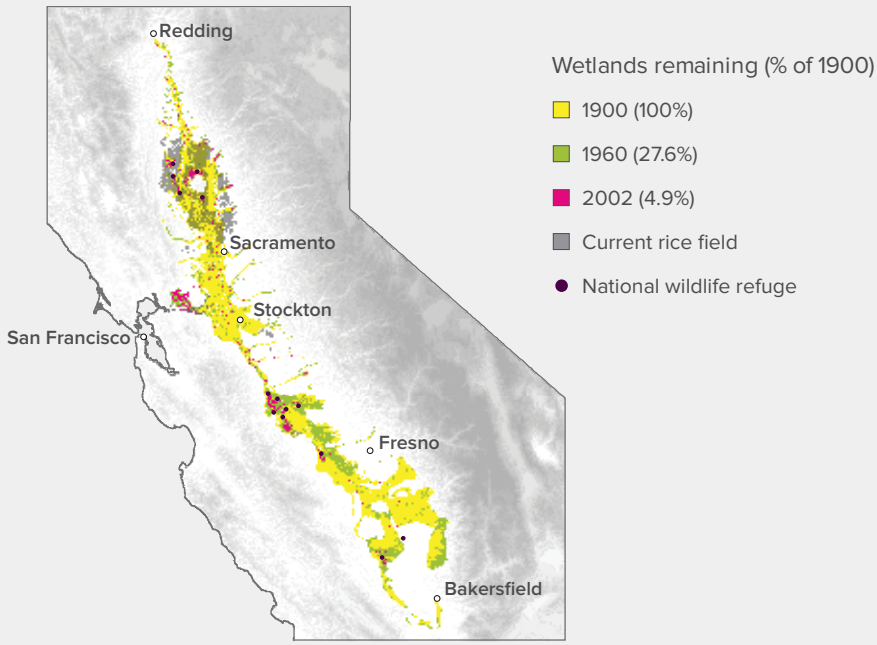
Although additional freshwater flows will likely be required to improve ecosystem conditions in some regions, new strategies to improve the efficiency and effectiveness of environmental water management are also needed.

- **Reduced flows are not the only source of ecosystem stress.**
  Habitat loss, water pollution, invasive species, and fishery and wildlife management practices also need to be addressed. It is not possible to undo all the ecological changes that have occurred over decades of human water and land use. Environmental managers and regulators need to find strategies that adapt to changing conditions.
- **Environmental water can get more "pop per drop."**
  Managing environmental water to mimic the variability of natural flows can produce significant ecosystem improvements, even with smaller flow volumes than would occur under natural conditions. Where and when water is used also matters. A little applied in the right place at the right time can go a long way, such as providing adequate flows and cool waters for salmon spawning, or expanding wetland acreage during bird migrations.
- **Restoring habitat requires water *and* land.**
  Riparian zones, floodplains, and wetlands require periodic flooding to provide high-quality habitat. Changing the timing of releases from reservoirs and removing or setting back levees can accomplish this. Removing dams no longer useful for water supply, flood control, or hydropower can restore fish access to good upstream habitat.

A large dam was recently removed on the Carmel River, and four more are planned to come down on the Klamath River. Habitat restoration should focus on areas of significant value for fish and wildlife. For example, the North Delta Habitat Arc, extending from the Yolo Bypass to Suisun Marsh, may be the best place to conserve and recover several salmon runs and other endangered Delta fishes.

- **Farming can be wildlife friendly.**
  Central Valley rice farms provide essential habitat for migratory waterfowl. Corn and alfalfa fields support many other types of birds. The Yolo Bypass creates habitat for birds and juvenile salmon, supports farming, and protects Sacramento from flooding. Throughout the region, farmers face economic pressure to shift to crops that have low habitat value but earn higher profits, such as fruits, nuts, and vegetables. Conservation easements, property tax reductions, and other financial incentives can help encourage farmers to practice wildlife-friendly land and water management.

CENTRAL VALLEY RICE FIELDS AND MANAGED WETLANDS PROVIDE WILDLIFE HABITAT



SOURCE: Updated from E. Hanak et al., *Managing California's Water: From Conflict to Reconciliation* (PPIC, 2011), Figure 1.2.

NOTES: Wetlands in 1900 include yellow, green, and red areas; the 1960 wetlands include green and red areas. Rice field acreage is from 2014. Rice fields perform some seasonal wetland functions for migrating birds and terrestrial and riparian species such as the giant garter snake.

Looking ahead

California has a long-term economic and social interest in supporting native biodiversity in freshwater ecosystems. But new approaches are needed to make environmental water allocations more effective and resilient to a changing climate.

Develop environmental stewardship plans. Adapting to a warmer, more variable climate requires watershed-level planning for freshwater ecosystems. These plans should inform water supply and flood management decisions and identify actions to be taken in advance of droughts. Examples include water acquisitions, habitat restoration, and investments in environmental strongholds that can support species during dry and warm periods (such as streams fed by cold water springs). Plans should also identify actions to speed recovery after drought.

Give the environment a water budget. Current methods of allocating water to support ecosystem health rely on minimum flow standards that are unevenly enforced and often insufficient during drought. Ecosystem water budgets, which allocate a portion of water to the ecosystem within watersheds, could enable more flexible and effective environmental management. This approach creates new opportunities for partnerships with other water users and can help reduce conflict over scarce supplies.

Reform environmental permitting. Environmental restoration projects often require multiple (and sometimes conflicting) permits, which can limit incentives for participation and the amount of habitat restored. The Habitat Restoration and Enhancement Act of 2014 reduces permitting hurdles for private landowners seeking to improve habitat—a model worth expanding.

Promote projects with multiple benefits. Water can simultaneously provide benefits to people and nature. For example, wildlife-friendly farming can support ecosystems while maintaining the economic viability of farms. Cooperation on storing and releasing water from reservoirs can benefit fish and meet downstream users' needs. Investing in healthy watersheds can protect drinking water and provide recreational opportunities.

Improve accounting for environmental water. More timely, transparent tracking of water use and availability is key to reducing misunderstandings and conflict over the use of water for different environmental purposes.

Provide reliable funding for ecosystem stewardship. California has relied heavily on state general obligation bonds to support freshwater ecosystems. Although helpful, bond funding is short-lived and project-based. California needs a new approach to funding ecosystem management, such as a small surcharge on water use.

CONTACT A PPIC EXPERT

Jeffrey Mount
mount@ppic.org

Caitrin Chappelle
chappelle@ppic.org

Brian Gray
gray@ppic.org

Ellen Hanak
hanak@ppic.org

CONTACT THE RESEARCH NETWORK

John Eadie, jmeadie@ucdavis.edu
Richard Frank, rmfrank@ucdavis.edu
Ted Grantham, tgrantham@berkeley.edu
Yusuke Kuwayama, kuwayama@rff.org
Jay Lund, jrlund@ucdavis.edu
Peter Moyle, pbmoyle@ucdavis.edu
Nathaniel Seavy, nseavy@pointblue.org
Leon Szeptycki, leonsz@stanford.edu
Joshua Viers, jviers@ucmerced.edu

READ MORE

- CLIMATE CHANGE AND WATER
- THE COLORADO RIVER
- ENERGY AND WATER
- MANAGING DROUGHTS
- PAYING FOR WATER
- PREPARING FOR FLOODS
- PROTECTING HEADWATERS
- PROVIDING SAFE DRINKING WATER
- THE SACRAMENTO–SAN JOAQUIN DELTA
- STORING WATER
- WATER FOR CITIES
- WATER FOR THE ENVIRONMENT
- WATER FOR FARMS

This series is supported by the annual sponsors of the PPIC Water Policy Center.

The PPIC Water Policy Center spurs innovative water management solutions that support a healthy economy, environment, and society—now and for future generations.

The Public Policy Institute of California is dedicated to informing and improving public policy in California through independent, objective, nonpartisan research. We are a public charity. We do not take or support positions on any ballot measure or on any local, state, or federal legislation, nor do we endorse, support, or oppose any political parties or candidates for public office. Research publications reflect the views of the authors and do not necessarily reflect the views of our funders or of the staff, officers, advisory councils, or board of directors of the Public Policy Institute of California.

Public Policy Institute of California
500 Washington Street, Suite 600
San Francisco, CA 94111
T 415.291.4400 F 415.291.4401
PPIC.ORG/WATER

PPIC Sacramento Center
Senator Office Building
1121 L Street, Suite 801
Sacramento, CA 95814
T 916.440.1120 F 916.440.1121

PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA

PPIC

Water for Farms

PPIC WATER POLICY CENTER

NOVEMBER 2018

California's farms face growing water management challenges

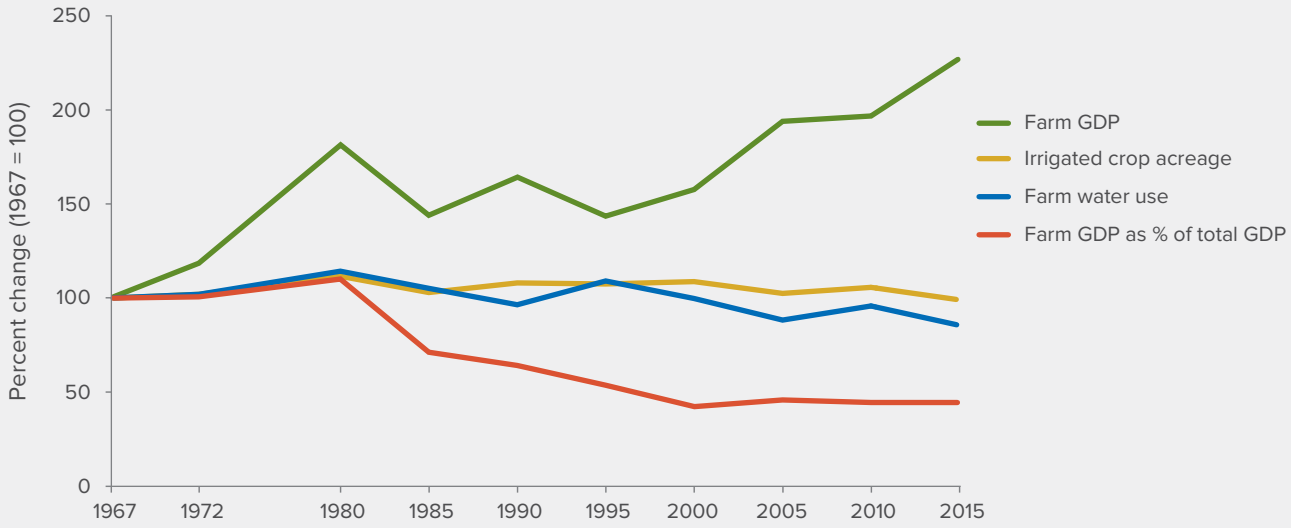
California is an agricultural powerhouse—the nation's largest farm state and a world market leader, with 2017 sales of $50 billion. Its dry summers make irrigation essential. Farmers use about 40 percent of available water to irrigate some 9 million acres of crops. Cities use 10 percent, and the remaining half is categorized as environmental water.

Farmers have steadily improved productivity and shifted to crops like fruits, nuts, and vegetables. These generate more revenue and profit per unit of water, as well as more farm jobs. Adjusted for inflation, the value of farm output and related food processing has more than doubled since the late 1960s despite little change in acreage or water used. But California's nonfarm sectors have grown faster, and agriculture is now around 2 percent of the state economy.

Water is an enduring concern. Many farmers get surface water from federal, state, and local projects. Many also pump groundwater. In some regions, groundwater reserves have been shrinking for decades. Since the 1980s, environmental regulations have limited—and sometimes cut—surface water supplies, thereby prompting more groundwater use. Pumping increased dramatically during the 2012–16 drought, causing dry wells and infrastructure damage from sinking lands. This prompted the landmark Sustainable Groundwater Management Act (SGMA), which requires water users to develop and implement plans to bring their basins into long-term balance.

SGMA could build agriculture's resilience to droughts, which are expected to become more severe as the climate changes. Farmers also need to improve water quality management. Local and regional efforts—with state and federal support—present opportunities to make progress in addressing these challenges.

THE VALUE FROM FARM WATER IS RISING, BUT FARMING IS DECLINING AS A SHARE OF THE ECONOMY



SOURCE: Author calculations using data from the US Bureau of Economic Analysis (total GDP), the US Department of Agriculture (farm GDP), the California Department of Water Resources (water and land use through 2010), and UC Davis (water and land use data for 2015, as summarized in Table A5 of E. Hanak et al., *What If California's Drought Continues?* (PPIC, 2015).

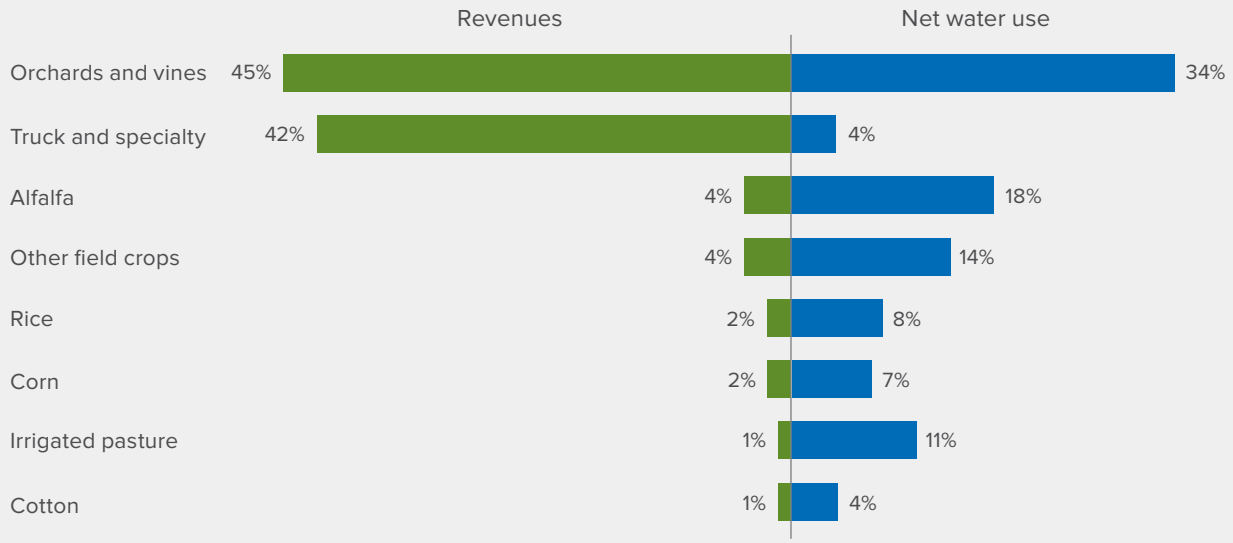
NOTES: GDP is California's gross domestic product, adjusted for inflation. Farm GDP is for primary crop and animal production and other farm-related income. Irrigated crop acreage includes land used for multiple crops within a year. Farm water use is the amount applied to fields. Net water use—the volume consumed by plants, evaporated, or discharged to saline waters—is lower, but reliable long-term estimates are unavailable. Pre-2000 estimates are adjusted to levels for a year of normal rainfall. Estimates from 2000 onward are for actual use in years with near-normal precipitation, except 2015, a critically dry year. Estimates omit conveyance losses and active groundwater recharge.

Farm water use is changing

California's agriculture is diverse, with more than 400 commodities produced in several major farming regions. Irrigated farmland is concentrated in the Central Coast, the Sacramento and San Joaquin Valleys, and parts of Southern California. Farmers respond continually to changing market and technological opportunities. These adaptations have boosted earnings and raised the value of scarce water supplies. But they have also brought new challenges.

- **Acreage is moving toward higher-revenue but less-flexible crops.**
  California farmers have shifted markedly to fruits, nuts, vegetables, and nursery crops. In 2012, these made up 47 percent of irrigated acreage, 38 percent of farm water use, and 86 percent of crop revenue. Forage crops such as alfalfa and corn silage—inputs for the large dairy and cattle industries—generate less direct revenue per unit of water. The water-limited San Joaquin Valley is home to roughly half of all irrigated acreage. Between 2000 and 2016, its orchards increased from 34 to 46 percent of irrigated cropland. This rise in nut and fruit orchards—which must be watered every year—has reduced farmers' ability to withstand intermittent water shortages. The region is also home to more than 80 percent of California's dairy cows. And because silage for dairies is costly to transport, corn and other silage is also fairly inflexible here, at more than 20 percent of total acreage.
- **Water delivery and field irrigation efficiencies are rising, bringing trade-offs.**
  Many irrigation districts have been upgrading delivery systems to provide more flexible service and to minimize canal spills and seepage. Federal and state grants have helped farmers switch from flood- to drip- and micro-irrigation. These improve crop yields and quality, reduce the application of water and chemicals, and help prevent chemicals from seeping into aquifers. However, in some regions—especially the San Joaquin Valley—these upgrades have the unintended consequence of lowering groundwater levels. That is because irrigation water not consumed by crops is a major source of groundwater recharge.
- **Groundwater is becoming more important—and more threatened.**
  Even before the latest drought, San Joaquin Valley farmers were pumping more groundwater to replace surface water previously shipped through the Sacramento–San Joaquin Delta or diverted from the San Joaquin River, as both those sources have been decreased to support endangered fish habitat. Groundwater is also being used to establish new orchards in previously unirrigated areas that lack surface water. High returns on orchard crops have made it profitable for farmers to invest in deeper wells, which further aggravates depletion. In some areas, groundwater quality is also declining—nitrate from farm runoff seeps into aquifers and harms drinking water, and salt buildup in groundwater and soils lowers crop yields.

CALIFORNIA HAS A DIVERSE CROP MIX, WITH WIDE VARIATIONS IN REVENUE AND WATER USE



SOURCE: Author calculations using data from the California Department of Water Resources (2010 water use) and the National Agricultural Statistics Service (2012 crop prices). Revenues are estimated using the Statewide Agricultural Production (SWAP) model.

NOTES: Total 2010 net water use for crops was 20.2 million acre-feet (maf), versus 29 maf applied to fields. Total 2012 crop revenues were $36.4 billion; dairy cattle and milk brought in $6.9 billion and other animal production brought in $2 billion. Alfalfa, corn, and irrigated pasture are key inputs for animal production. Crop revenues do not sum to 100 percent because of rounding. Truck and specialty includes non-tree fruits, vegetables, flowers, and garden plants.

California needs to manage farm water for the long term

California will continue to be an agricultural leader, but it must keep adapting and focus on sustainably managing both water quantity and quality. To achieve this goal, farmers will likely farm less acreage but more intensively.

- **Better groundwater management is a top priority.** Groundwater is a major asset for California agriculture, especially during droughts. But farmers could traditionally pump without quantity restrictions—a practice that has lowered reserves and caused other problems. SGMA now requires water users to manage their basins for the long term. By mid-2017, more than 250 groundwater sustainability agencies (GSAs) were formed in 140 basins. The first plans are due in early 2020, and GSAs will have 20 years to achieve sustainability. If they fail to prepare or implement plans, the State Water Board can take over. Bringing basins into balance will require increasing recharge. And in the most stressed basins—particularly in the San Joaquin Valley and Central Coast—it will likely require pumping less and reducing irrigated cropland.
- **Better integration of surface water and groundwater management is key.** Many irrigation districts already manage surface and groundwater resources jointly to encourage groundwater basin replenishment in wet years. These local efforts need to increase. In addition to recharging in dedicated basins and unlined canals, spreading excess winter flows on farmland is promising but requires careful consideration of water quality. Shifting the timing of reservoir releases could increase the availability of surface water for underground storage. To facilitate recharge, some areas will need infrastructure upgrades—especially of conveyance.
- **Water markets provide essential flexibility.** California farmers have been active participants in the state's water market for more than two decades. This market has supported productive farming areas that lack reliable supplies, and it helped keep orchards alive during the latest drought. Markets also make water available for the environment and growing urban areas and provide revenue to farmers who sell it. Trading partnerships between Southern California farmers and cities are helping that region adapt to growing scarcity of Colorado River water. Localized trading of groundwater pumping rights within basins can help implement the new groundwater law by allowing farmers who need more water for their orchards and other high-revenue crops to compensate other farmers for reducing use.
- **Agricultural stewardship can do more to support the environment.** Further improvements in irrigation practices will reduce harmful discharges, as will better management of agricultural chemicals and drainage. Soil management on rangelands and idled cropland can improve air quality and sequester carbon. Beneficial on-farm practices that provide habitat for California's fish and wildlife also merit expansion, with programs to compensate farmers for these services. Federal Farm Bill programs offer assistance for a range of stewardship activities, and some state programs can also help.

Looking ahead

Farmers and irrigation districts are the frontline stewards of agriculture's future, but the state and federal governments can provide technical, regulatory, and financial support to help California agriculture adapt to changing conditions.

Support local groundwater management. Groundwater sustainability agencies can monitor, manage, and charge for groundwater pumping and the cost of recharge programs. And 2015 legislation makes it easier for them to allocate pumping rights. But achieving sustainable groundwater use will be difficult and controversial—especially in areas where pumping must decline. State bonds provide resources for local planning, and the state can contribute valuable technical support and guidance.

Improve water information. Successful groundwater management requires developing good accounts to track water use, pumping, and recharge. Data remain fragmented and often rudimentary regarding groundwater use, water use by crops, and other key information. California also needs to employ more advanced technology such as remote sensing, which can enhance or replace sometimes costly, less reliable data collection on the ground.

Facilitate recharge and water trading. One urgent state priority is to clarify water available for groundwater recharge. Trading water is an important way for farmers to decrease the costs of drought and reductions in groundwater pumping. Federal, state, and local agencies should do more to simplify and expedite the approval process for trading.

Improve water infrastructure. California's water infrastructure—including reservoirs and aqueducts—is aging and needs an upgrade. Regional and local conveyance investments are critical to support groundwater recharge and trading and to maintain water supplies drawn through the Delta, which could be disrupted by rising seas, seasonal flooding, and earthquakes. Some state and federal funding is available to support these efforts, but agricultural and urban water users will need to shoulder much of the cost.

Support farmworker communities. Continued progress is needed to provide safe drinking water in rural communities where groundwater is contaminated, and where shallow domestic wells are at risk from falling levels. Farmworkers are also vulnerable to losing jobs, commuting longer distances, or having their hours reduced when cropland is fallowed due to water scarcity. Emergency financial and food assistance helped during the latest drought. Beyond that, the state and federal governments should support workforce development to help rural communities adapt to the changing farm economy.

Encourage regional collaboration. Much of the initial planning for groundwater sustainability is occurring at the very local scale. But many promising approaches for meeting sustainability goals—including groundwater recharge and water trading—will require broader collaboration. Regional approaches can also help address other challenges—such as safe drinking water and environmental stewardship. The state should incentivize collaboration through its allocation of bond funds.

CONTACT A PPIC EXPERT

Ellen Hanak
hanak@ppic.org

Alvar Escriva-Bou
escriva@ppic.org

Jelena Jezdimirovic
jezdimirovic@ppic.org

CONTACT THE RESEARCH NETWORK

Sarge Green, sgreen@mail.fresnostate.edu
Thomas Harter, thharter@ucdavis.edu
Jay Lund, jrlund@ucdavis.edu
Josué Medellín-Azuara, jmedellin-azuara@ucmerced.edu
Doug Parker, doug.parker@ucop.edu
Daniel Sumner, dasumner@ucdavis.edu

READ MORE

- CLIMATE CHANGE AND WATER
- THE COLORADO RIVER
- ENERGY AND WATER
- MANAGING DROUGHTS
- PAYING FOR WATER
- PREPARING FOR FLOODS
- PROTECTING HEADWATERS
- PROVIDING SAFE DRINKING WATER
- THE SACRAMENTO–SAN JOAQUIN DELTA
- STORING WATER
- WATER FOR CITIES
- WATER FOR THE ENVIRONMENT
- WATER FOR FARMS

This series is supported by the annual sponsors of the PPIC Water Policy Center.

The PPIC Water Policy Center spurs innovative water management solutions that support a healthy economy, environment, and society—now and for future generations.

The Public Policy Institute of California is dedicated to informing and improving public policy in California through independent, objective, nonpartisan research. We are a public charity. We do not take or support positions on any ballot measure or on any local, state, or federal legislation, nor do we endorse, support, or oppose any political parties or candidates for public office. Research publications reflect the views of the authors and do not necessarily reflect the views of our funders or of the staff, officers, advisory councils, or board of directors of the Public Policy Institute of California.

Public Policy Institute of California
500 Washington Street, Suite 600
San Francisco, CA 94111
T 415.291.4400 F 415.291.4401
PPIC.ORG/WATER

PPIC Sacramento Center
Senator Office Building
1121 L Street, Suite 801
Sacramento, CA 95814
T 916.440.1120 F 916.440.1121

PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA

THANK YOU TO THE ANNUAL SPONSORS OF THE PPIC WATER POLICY CENTER

PPIC
PUBLIC POLICY INSTITUTE OF CALIFORNIA

Public Policy Institute of California
500 Washington Street, Suite 600
San Francisco, CA 94111
T 415.291.4400 F 415.291.4401

PPIC Sacramento Center
Senator Office Building
1121 L Street, Suite 801
Sacramento, CA 95814
T 916.440.1120 F 916.440.1121

ppic.org/water

This publication is printed on post-consumer recycled paper.